(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 324 277 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 88312338.2

(22) Date of filing: 28.12.88

(51) Int. Cl.4: H04L 11/16 , H04L 11/00

(30) Priority: 15.01.88 US 145443

(43) Date of publication of application: 19.07.89 Bulletin 89/29

(84) Designated Contracting States: AT BE CH DE ES FR GB GR IT LI LU NL SE

(71) Applicant: VITALINK COMMUNICATIONS CORPORATION
6607 Kaiser Drive
Fremont California 94555(US)

(72) Inventor: Hart, John Henry
1171 Lenor Way
San Jose California 95128(US)

(74) Representative: Calderbank, Thomas Roger et al
MEWBURN ELLIS 2 Cursitor Street
London EC4A 1BQ(GB)

(54) Distributed load sharing.

(57) Methods and apparatus for exchanging frames between bridges distribute load sharing in a communications network. The communications network is of the kind in which bridges, and related stations and local LANs, e.g. Ethernet LANs and 802 LANs, can be linked by paths in a plurality of sub-networks and wherein the bridges are linked to support a Spanning Tree Protocol (STP) which elects one bridge as a root and then with respect to said root, computes and utilizes one and only one loop-free set of primary paths between all bridges. Remaining paths, i.e. paths other than said STP primary paths, between the bridges are examined as possible sub-network paths for a Distributed Load Sharing (DLS) configuration in which frames exchanged between certain stations can utilize more than the STP one set of primary paths. Certain ones of the remaining paths are selected as DLS paths under certain conditions and frames are routed over a selected DLS path only when those frames meet certain criteria.

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DISTRIBUTED LOAD SHARING

This invention relates to methods and apparatus for exchanging frames between bridges to distribute load sharing in a communications network of the kind in which bridges, and related stations and local LANs, e.g. Ethernet LANs and 802 LANs, can be linked by paths in a plurality of sub-networks and wherein the bridges are linked to support a Spanning Tree Protocol (STP) which elects one bridge as a root and then, with respect to said root, computes and utilizes one and only one loop-free set of primary paths between all bridges.

This invention relates particularly to methods and apparatus for examining remaining paths, i.e. paths other than said STP primary paths, between the bridges as possible sub-network paths for a Distributed Load Sharing (DLS) configuration in which frames exchanged between certain stations can utilize more than said STP one set of primary paths between the stations. Certain ones of the remaining paths as are then selected as DLS paths only when certain conditions are met and frames are routed over a selected DLS path only those frames meet certain criteria.

Each of the following documents are of general interest in considering this invention.

(1) The Ethernet, A Local Area Network Data Link Layer and Physical Layer Specifications, Version 2.0, Nov. 1982;

(2) ANSI/IEEE Std 802.3-1985 ISO Draft International Standard 8802/3 -- An American National Standard IEEE Standards for Local Area Networks: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications;

(3) ANSI/IEEE Std 802.4-1985 ISO Draft International Standard 8802/4 -- An American National Standard IEEE Standards for Local Area Networks: Token-Passing Bus Access Method and Physical Layer Specifications;

(4) ANSI/IEEE Std 802.5-1985 ISO Draft Proposal 8802/5 -- An American National Standard IEEE Standards for Local Area Networks: Token Ring Access Method and Physical Layer Specifications;

(5) IEEE Project 802 Local and Metropolitan Area Network Standards, IEEE Standard 802.1 (D) MAC Bridges (The Spanning Tree Protocol); and

(6) United States Patent No. 4,706,081 entitled "Method and Apparatus for Bridging Local Area Networks" issued November 10, 1987 to Hart, et al., and assigned to Vitalink Communications Corporation.

The trademark "TransLAN" is registered in the United States Patent and Trademark Office and is owned by Vitalink Communications Corporation. This TransLAN trademark is used by Vitalink Communications Corporation on hardware and software for the configurations and methods of the communications system disclosed in the above noted U.S. Patent No. 4,706,081. The trademark TransLAN is used below in the present application in reference to such hardware and software for the configurations and methods of the communications system disclosed in U.S. Patent No. 4,706,081.

The Spanning Tree Protocol (STP) computes primary paths between all bridges in a communications network of the kind in which the bridges, and related stations in local LANs, e.g. Ethernet LANs and 802 LANs, can be linked by paths in a plurality of sub-networks.

The Spanning Tree Protocol (STP) elects one bridge as a root and then, with respect to said root, computes and utilizes one and only one loop-free set of primary paths between all the bridges.

Some of the remaining paths, i.e. paths other than said STP primary paths between the bridges can, in the STP protocol, be designated as backup paths under certain conditions; but the STP protocol transfers frames only on the primary paths, and not on any of the remaining paths, so long as the primary paths remain effective to function (until some event occurs which requires a re-configuration of the primary paths in the STP protocol).

It is a primary object of the present invention to distribute load sharing in a network in which bridges are linked to support STP by using paths additional to the primary paths for transferring frames between bridges.

It is a related object to distribute load sharing in a way which preserves loop-free paths between all bridges.

The methods and apparatus of the present invention exchange frames between bridges to distribute load sharing in a communication network of the kind in which bridges, and related stations in local LANs, e.g. Ethernet LANs and 802 LANs, can be linked by paths in a plurality of sub-networks and wherein the bridges are linked to support a Spanning Tree Protocol (STP) which elects one bridge as a root and then, with respect to said root computes and utilizes one and only one loop free set of primary paths between all bridges

The present invention examines remaining paths, i.e. paths other than said STP primary paths, between the bridges as possible sub-network paths for a Distributed Load Sharing (DLS) configuration in which frames exchanged between certain stations can utilize more than said STP one set of primary paths between the stations.

The methods and apparatus of the present invention select certain ones of the remaining paths as DLS paths only when

(a) the two bridges interfacing to the DLS path also interface to one or more other sub-networks and neither is the STP root bridge.

The present invention routes over a selected DLS path only those frames

(a) which have a known single destination, and

(b) which are frames to be transferred between stations (1) which are further away from the root than either bridge associated with said stations or (2) which lie on the bridge's local LAN.

The present invention configures the bridges at the ends of a DLS path to know which stations are farther away from said root so that frames are not transferred between stations whose source network is an STP inlink on either bridge unless the STP inlink on either bridge is the local LAN.

A DLS path end point extension feature (DLS Extension) allows support DLS paths by bridges with only two networks and also applies to bridges with more than two networks.

The DLS Extension feature of the present invention allows frames to be exchanged between stations located on inlinks of bridges interfacing to a DLS path. In addition the DLS Extension feature allows frame exchanges between stations located further away from the root than one or both bridges interfacing to a DLS path.

Station addresses are switched between an STP path and selected DLS paths while preserving first-in first-out (FIFO) frame exchange while switching the station addresses.

Self learning bridges on a potential DLS path are configured (a) to recognize when said bridges are on a potential DLS path, (b) to let the related bridge on the DLS path know of said recognition, (c) to decide whether the related bridge is on the DLS path, (d) to agree with the related bridge to form the DLS path, (e) to advertise to the related bridge which stations are appropriate to use the DLS path, (f) to flush the STP path with a flush packet prior to switching stations over to start using the DLS path to thereby preserve first-in first-out (FIFO) frame exchange between stations, then (g) to start switching stations over to using the DLS path.

Steps (f) and (g) above are performed in reverse prior to switching a DLS path over to an STP path.

The data stores for each of the sub-networks are configured for operation with STP and DLS paths.

Methods and apparatus which incorporate the features described above and which are effective to function as described above constitute further, specific objects of the invention.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings, which by way of illustration, show preferred embodiments of the present invention and the principles thereof and what are now considered to be the best modes contemplated for applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

Figure 1 through Figure 5 are views of communication networks having bridges linked by primary paths to support a Spanning Tree Protocol (STP). The captions included in Figures 1 - Fig. 5 summarize, in each respective figure, how the Distributed Load Sharing (DLS) feature of the present invention affects or allows frame exchange between the bridges along the primary paths provided by STP and along additional paths provided by DLS. The STP paths are indicated by the solid lines.

Figures 3-1 through Figure 3-11 (like Figure 1 through Figure 5 above) show communications networks in which > bridges are linked to support STP. The paths indicated by the solid arrows indicate the STP paths. Figure 3-1 through Figure 3-11 are used to illustrate a DLS overview. These figures illustrate how the present invention examines remaining paths, i.e. paths other than the STP primary paths, between the bridges as possible sub-network paths for the DLS configuration and illustrate how the present invention selects certain ones of the remaining paths as DLS paths only when certain conditions are met. These figures illustrate how frames are routed over the selected DLS paths only when the frames comply with certain criteria.

Figure 4 through Figure 4.5 show the format of the protocol data units of the different types of protocols required to communicate information in the DLS methods and apparatus of the present invention.

Figure 5 through Figure 5.4 relate to the data stores of the DLS methods and apparatus of the present invention and illustrate the data stored variables which are required and which have to be maintained by the distributed protocol of the DLS methods and apparatus of the present invention.

Figure 6 is a chart showing the operation of the DLS methods and apparatus of the present invention. Figure 6 shows the bridge port states in columns and the events in the rows, as labeled.

Figure 6.5 shows details of the state changes which occur upon receipt of the event shown in the fifth row of Figure 6 (the receipt of the event "DLS Hello PDU Processing"). The state changes associated with the other events listed in Figure 6 are filled in very much the same fashion as the state changes illustrated in Figure 6.5.

Section 1 - Overview

Bridges supporting the Spanning Tree Protocol (STP) collectively utilize one loop free set of paths between all Bridges. In contrast, topologies with loops present fewer problems to Routers. Routers, which do not learn from a frames source, are free to independently pick their set of paths (i.e. computer own spanning tree) and, as a result, can independently utilize alternate paths. This document defines TransLAN Distributed Loan Sharing (DLS) feature which provides an equivalent or greater level of flexibility for most configurations.

When a Network is labeled by STP as a Backup network, its role is that of a hot standby. Unless there is a network failure, its bandwidth is not available for exchange of frames between stations.

Figure 1 illustrates that DLS removes this restriction by allowing frames exchanged between stations on Bridge B's Ethernet and stations on Bridge C's Ethernet to utilize more than one path. Instead of traveling only on the STP path across Network B-A and then Network A-C (termed path B-A-C), DLS allows the frames to also be forwarded across the STP Backup Network B-C, termed DLS path B-C. Furthermore, the DLS load sharing potential increases as the configuration expands.

The Figure 2 configuration shows that DLS allows the exchange of frames between Bridge B or D Ethernet stations and Bridge C, E, or G Ethernet stations to be load shared across STP path B-A-C and DLS path B-C. However, as illustrated in Figure 3, frames exchanged between Bridge A and Bridge F Ethernet stations and any other Bridge Ethernet Stations (i.e. B,C,D,E, and G) use only STP paths.

What the Figure 2 and 3 configurations point out is that load sharing across DLS path B-C impacts the exchange of frames between stations only when both of the following are true:

- the STP path between the stations traverses both Bridge B and Bridge C (i.e. the Bridges interfacing to the Backup Network);
- from an STP perspective one of the stations is positioned further away from Root than Bridge B and the other from Bridge C.

Another important DLS feature is that tandem DLS paths can be configured by concatenating shorter DLS paths together. To illustrate this feature, the above configuration is further expanded by adding a network between Bridge A and Bridge G. This results in STP labeling the new Network (Network G-A) as the Inlink for Bridge G and labeling Network G-C, the old Inlink, as a STP Backup Network. Backup Network G-C can now become a DLS path. After this occurs, tandem DLS path B-C-G can be established. The DLS frame exchanges in the resulting configuration are illustrated in Figure 4.

In Figure 4, the exchange of frames between Bridge G Ethernet stations and both Bridge C and E Ethernet stations is load shared over path G-A-C and G-C (and then across C-E when exchanging frames with Bridge E Ethernet stations). Likewise, the exchange of frames between Bridge G Ethernet stations and both B and D Ethernet stations is load shared over path G-A-B and G-C-B (and then across B-D when exchanging frames with D Ethernet stations). The exchange of frames between Bridge B or D Ethernet stations and Bridge C or E Ethernet stations continues to be load shared over path B-A-C and B-C as described earlier.

In Figures 1-4, a bridge interfacing to a DLS path always contains more than two Networks and the stations that utilize the DLS path are located on networks that are further away from the Root than the bridge (i.e., the stations are not on the Inlink path to the STP root bridge). This characteristic would seem to preclude support of DLS paths by bridges with only two networks because, if one network is a DLS path, the other must be the Inlink path.

Consequently, the bridge sees all stations as closer to the Root.

The DLS path endpoint extension feature (termed DLS Extension) allows support DLS paths by bridges with only two networks.

Figure 5 illustrates that the DLS Extension feature involves the cooperation of the bridge interfacing directly to the DLS path and the Designated Bridge on its Ethernet Inlink. Together bridges B′ + B and C′ + C support DLS path B′-C′. DLS path B′-C′ supports frame exchanges between stations on the Site B Ethernet and stations on the Site C Ethernet. Since Bridge C′ has three networks, Figure 5 illustrates that the DLS Extension feature also applies to bridges with more than two networks.
In summary, the DLS Extension feature allows frames to be exchanged between stations located on the Ethernet Inlinks of the bridges interfacing to a DLS path. In addition, the DLS Extension feature allows frame exchanges between stations located further away from the Root from one or both bridges interfacing to a DLS path (e.g. DLS Extension allows frame exchanges between stations on the Site E Ethernet and stations on the Site B Ethernet).

Section 1.1 - Feature List

The following list summarizes the TransLAN Release 6.9 DLS features.

1. Automatically utilize a network as a DLS path only when the two bridges interfacing to the DLS path also interface to two or more other networks and neither is the STP Root Bridge.

2. Provide an REC configuration capability to either prevent a DLS path from forming or restrict the number of stations allowed to utilize it. When the Backup Network has a higher cost than the STP path between the two bridges, the number of stations allowed to utilize the DLS path will always be restricted using this capability.

3. Route only the following frames over a DLS path:

- known single destination frames. Multicast and unknown single destination frames always use the STP route.
- frames to be transferred between stations (1) which are further away from the root than either bridge associated with said stations or (2) which lie on the bridge's local LAN.

4. Automatically learn the station addresses that utilize the DLS path.

5. Load share between the DLS and STP path.

6. Provide as an option the ability to preserve FIFO while switching station addresses between an STP path and DLS path and vice versa.

7. Support tandem DLS paths made up of one to four shorter DLS paths.

8. Support up to 4 DLS Extensions across a single Ethernet inlink. This includes tandem DLS paths and/or DLS paths supported by multiple bridges with the same Ethernet inlink.

Section 2 - External Reference Specification

This Section describes the changes and additions to the reconfiguration and view screens and the new Commands required for DLS support.

Section 2.1 - Reconfiguration and View Screens

The following rec screens contain the new DLS Variables (in Bold).

Section 2.1.1 - TransLAN General DLS Variables

/1/2/?/?	DLS GLOBAL VARIABLES		Bridge B
	Variables	Current Value	
1.	Sector ID, Configured - Address	S	0x000000000000
2.	- Count	S	0
3.	- Tx Net	S	0x00000000000000
4.	Sector ID, Utilized - Address	D	0x08007C000065
5.	- Count	D	1
6.	- Tx Net Path	D	0x02000000000000
7.	DLS Round Trip Delay - Configured	S	4
8.	- Utilized	D	4
9.	DLS Interval - Configured	S	4
10.	- Utilized	D	4
11.	FIFO Required - Configured	S	True
12.	- Utilized	D	True
13.	Transmit Flush Frame - Configured	S	True
14.	- Utilized	D	True

Global Variables

All DLS Global Variables have Configured and Utilized values. The values configured into a TransLAN Spanning Tree Root bridge automatically become the utilized values in other TransLAN bridges. In configurations where a TransLAN bridge is not the root bridge (e.g. a LAN Bridge 100), the values can be configured into each TransLAN Bridge.

Sector ID (Configured and Utilized) contains the following values:

Address - Global Address of the Root Bridge
Count - the number of Networks to the Root Bridge (1-7). If there are more than seven, put 7.
Tx Net Path - the list of Transmit Network IDs from the Root to this Bridge. Each Transmit ID equals two hex digits (i.e. OxNN) in the list. If there are more seven Transmit IDs, put only the first seven.

DLS Round Trip Delay (Configured and Utilized)

Indicates in a Bridge with one or more DLS Networks, the worst case round trip delay through the spanning tree Root Bridge and then back across the DLS Network. The **Configured DLS Round Trip Delay** values can range from 4 to 32 seconds. The default value is 4. This default value is computed from the simple DLS configuration illustrated in Figure 3-1. In this configuration the DLS round trip path for Bridge B goes from B to A to C and then back to B. Since the worst case delay within a Bridge is normally restricted to 1 second (i.e. the rec default configuration value), the default value of 4 was picked by adding 1 second for queuing in Bridge B, A, C and then adding 1 second for overall transmission/processing time. In configurations where the DLS round trip is longer, the **Configured DLS Round Trip Delay** value should be increased (see **Round Trip Delay Expired Count** below).

DLS Interval (Configured and Utilized)

Indicates in a Bridge with one or more DLS Networks, how often station addresses will be advertised for switching between the STP and the DLS Path. The **Configured DLS Interval** values can range from 4 to 32 seconds. The Default value is 4. This default value is a good choice for most configurations. An exception to this may occur in configurations with low bandwidth networks (e.g. 9.6 kbps). In these configuration, the **Configured DLS Interval** value can be increased in order to reduce DLS Protocol overhead.

FIFO Required (Configured and Utilized)

Indicates if address's source network can immediately be moved between the "old" STP and a "new" DLS path, or vice versa. If **FIFO Required** value is True.

Transmit Flush Frame (Configured and Utilized)

This variable is only meaningful when **FIFO Required** equals True (the default value) and defines the method for flushing the traffic associated with the "old" path. When **Transmit Flush Frame** is set to True, the "old" path is flushed by marking the address as "do not forward", transmitting a Flush frame, and setting a timer equal to the **DLS Round Trip Delay** value. Normally, an address's source network is changed to the "new" path and the "do not forward" removed when a Flush frame returns. If the Flush is lost, the source network is changed to the "new" path and the "do not forward" removed when the timer expires. The default **Transmit Flush Frame** value is True. Setting **Transmit Flush Frame** equal to false will normally lengthen the flush time but may be necessary in multivendor bridge environments.

Section 2.1.2 - TransLAN Local DLS Variables

/1/2/?/?	DLS LOCAL VARIABLES	Bridge B
	Variables	Current Value
1.	DLS Multicast	S 0x09007C...
2.	DLS Hello Multicast	S 0x09007C...
3.	DLS Inlink Hello Multicast	S 0x09007C...
4.	DLS and Non-DLS Multicast	S 0x09007C...
5.	DLS Networks	X 1
6.	Short Timers Invoked	X 9
7.	Round Trip Delay Expired Count	X 0

Local Variables

DLS Local variables are not changed by the values configured in the Spanning Tree Root bridge.

DLS Multicast

DLS Hello Multicast

DLS Inlink Hello Multicast

DLS and Non DLS Multicast

Indicates three Multicast Address values used by DLS.

DLS Networks

Indicates the number of DLS Networks in a Bridge.

Round Trip Delay Expired Count

Indicates in a Bridge with one or more DLS Networks, that either certain DLS Protocol Frames are being discarded during their round trip journey or the **DLS Round Trip Delay** value is too small. If a network in the round trip path has failed, Spanning Tree and/or Network Validation protocols will detect this failure and the value will stop increasing. Otherwise, if this is not the case, the **DLS Round Trip Delay** value (in the TransLAN Root) should be increased.

<u>Section 2.1.3 - Transmit Data Store Configurable Variables</u>

/1/2/2/1/?	TRANSMIT DATA STORE CONFIGURABLE VARIABLES		Network B-C
Variables		Current Value	
1.	Name		Network B-C
2.	Current State	D	DLS Backup
3.	Initial State	S	On
4.	If Broken, Why	D	CTS loss
5.	Network Topology		non rooted
6.	Link Type		terrestrial
	.		.
	.		.
	.		.

Current State

Indicates the Transmit Network State. The new **Current State** values are

DLS Backup

The Distributed Load Sharing logic sets **Current State** equal to DLS Backup if the Spanning Tree protocol logic determines that the value of **Current State** is equal to Backup, **Enable DLS** equals True (defined below), **Parallel Network and/or Network Validation** equals True and

1. The **Network Cost** of this network is less than the Spanning Tree cost of the path to the remote bridge on the network.

2. **Force DLS** = True (defined below).

3. The remote Bridges agrees that the network is a DLS path.

DLS Forwarding

The Distributed Load Sharing logic sets **Current State** equal to DLS Forwarding if the Spanning Tree protocol logic determines the value of **Current State** is equal to Forwarding, **Enable DLS** equals True (defined below), **Parallel Network and/or Network Validation** equals True, and the remote Bridge agrees that the network is a DLS path.

Section 2.1.4 - DLS Transmit Network Variables

/1/2/?/? Variables	Distributed Load Sharing Variables	Network B-C Current Value
1.	Enable DLS	S True
2.	Force DLS	S True
3.	FDSE Total	X 3 1
4.	FDSE Maximum	5 6

Enable DLS

If set to True for a point to point network, indicates that the Transmit Network **Current State** can be set to DLS Backup or DLS Forwarding as defined above. If set to True for the Ethernet, indicates DLS Extensions can occur. If set to False, indicates that neither DLS paths or DLS Extensions are supported across this network. The Default value equals False.

Force DLS

If set to False, indicates that Transmit Network **Current State** will only be set to DLS Backup when the Network cost of the Network is less than the Spanning Tree cost of the path to the remote bridge. If **Force DLS** is set to True, indicates that the **Network Cost** check is not made and that the **FDSE Maximum** value (defined below) is used to limit the number of stations using the DLS Network. The Default value equals True.

FDSE Total

The number of Single Destination Addresses which have an FDSE with a Source equal to this Network or set of Parallel Networks.

FDSE Maximum

Indicates the maximum number of FDSE's can be created for this Network or set of Parallel Networks while it is operating as a DLS Network (i.e. has a State equal to DLS Forwarding or DLS Backup). The Default value equals the Data Link **Baud Rate** divided by 1000.

Section 3 - DLS Design Overview

When a Bridge interfacing to more than 2 operational networks sets the **Current State** of one of the network's equal to Backup and the network's **Parallel Networks and/or Network Validation** variable equals True, it has the information necessary to determine if the network is a DLS Path. For example, in the Figure 3-1 below, Bridge B knows all of the following:

1. Network B-C's Cost (rec **Network Cost** =1786)
2. its cost to the Root (rec **My Cost** =1786)
3. Bridge C's cost to the Root (the **Hello Cost** in the STP Hello message received from Backup Network B-C equals 446).

From the above information, Bridge B determines that Network B-C can be a DLS Path because

```
B-C DLS Path Cost  < B-C STP Path Cost or
Network B-C Cost   < B's My Cost + B-C's Hello Cost or
1786               < 1786        + 446
```

If the DLS path is chosen in this fashion, all addresses of stations associated with B's Ethernet and Network B-D (i.e. addresses further away from the root) will be advertised to Bridge C as DLS Stations (i.e. addresses whose Source can be switched from the STP Path to DLS path B-C).

However, there is a way to limit Bridge B's use of DLS path B-C which also bypasses the above DLS/STP path cost comparison. If Transmit Network B-C's **Force DLS** equals True (the default value), Bridge B will automatically use Network B-C as a DLS path, but access to stations (advertised by Bridge C) across B-C is limited by the Transmit Network B-C variable termed **FDSE Maximum** (both **Force DLS and FDSE Maximum** are discussed in Section 2).

When Bridge B determines that Network B-C can be used as a DLS path, it notifies the Bridge C (i.e. the bridge that generated the Hello) of this fact. If Bridge C agrees then,

1. Bridge C sets Network C-B's Current State equal to DLS Forwarding.
2. Bridge B sets Network B-C's Current State equal to DLS Backup.
3. Both Bridges begin advertising to the other, station addresses to be switched from the STP Path to the DLS path (i.e. Network B-C). Station Addresses are advertised in DLS frames transmitted to the other Bridge. As stated in Section 1, the set of station addresses that are advertised, are those that are positioned further away from the Root than the Bridge (i.e. Bridge B advertises stations located on its Ethernet across Network B-D and Bridge C advertises stations located on its Ethernet and across Network C-E).

While in the Figure 3-1 configuration, Bridge C will always agree that Network B-C can be used as a DLS path, there are configurations where this is not the case. In Figure 3-2, Configuration 1, Network A-C can not be a DLS path because Bridge A is the Root. If Network A-C is allowed to become a DLS Network, Bridge B, and possibly Bridge C, will not function properly. Bridge A will advertise all addresses as potential DLS addresses. This will result in Bridge C setting Bridge B Ethernet stations and potentially even its local Ethernet Stations as accessible across DLS path C-A.

While Bridge C in Configuration 1 could possibly recognize and prohibit the reassigning of its local Ethernet Addresses, it could not stop the reassignment of Bridge B Ethernet stations. The later results in Bridge B seeing stations change locations almost continuously.

This location change occurs in Bridge B because, when a Bridge C Ethernet station (named station x) sends a single destination frame to a Bridge B Ethernet station that has been reassigned to DLS path C-A, the frame travels across path C-A-B and Bridge B assigns Network B-A as station x's source. When station x generates a multicast frame, the frame travels across STP path C-B-A and Bridge B assigns Network B-C as station x's source. Among other things, this constant change means that FIFO can not be guaranteed for frames transmitted to station x from Bridge B's Ethernet.

Likewise, if Network A-C in Configuration 2 above is allowed to become a DLS path, the same problems occur for Bridge B. In general, a DLS path can not be formed between two bridges located along the same STP path to the Root, because any Bridges located along the same STP path between the two Bridges will observe side changes and can not guarantee FIFO.

The DLS software automatically detects the Configuration 1 and 2 cases and prevents the DLS path from forming. The Configuration 1 case is easy to detect and prevent. DLS will not allow one end of a DLS

path to be connected to the STP Root Bridge. The Configuration 2 case is more challenging and requires the introduction of a new concept termed a **Sector ID.** This new concept is discussed below.

Sector ID's

One way of viewing Configuration 2 in Figure 3-2 is to organize it into sectors and sub-sectors. See Fig. 3-3.

Bridge D, the Root Bridge, is placed in the center of the configuration. Each of its networks that is used as part of a STP Path (i.e. not a Backup network), forms a sector. This results in Configuration 2 being divided into four sectors. Each sector is identified by the respective Transmit Network IDs (i.e. 1-4).

Bridge A is placed in the lower sector (i.e. Sector 3) which is further divided into two sub-sectors, one for each Bridge A network that is used as part of a STP path. Each of the two sub-sectors is identified by concatenating the Bridge A Transmit Network ID onto Sector ID 3. This results in the two sub-sector IDs equaling 3-1 and 3-2.

Bridge B is placed into sub-sector 3-2 which again is further divided into two sub-sectors, one for each Bridge B network that is used as part of a STP path. Each of the two sub-sectors is identified by concatenating the Bridge B Transmit Network ID onto sub-sector ID 3-2. This results in the two sub-sector IDs equaling 3-2-1 and 3-2-2. Bridge C is placed into sub-sector 3-2-2.

After all sub-sectors are created, the STP Backup networks are drawn (using dotted lines) between the sector/subsectors containing the Bridges to which they interface. If the dotted lines are pointed to/from the Root (as it is for Network A-C in Figure 3-3), the associated Network can not be a DLS network. Otherwise, it can.

The direction of the dotted line can be determined by analyzing the Sector ID's associated with the end-points. Network A-C's Sector IDs equal 3 and 3-2-2. Since 3 is completely contained with 3-2-2, Network A-C points to/from the Root - more about this later.

A much easier way to manually determine if the network is a DLS candidate is to draw in the STP path to the Root for the Bridges supporting a Backup Network's endpoints. If the STP path for one Bridge travels through the other, the Network is not a DLS candidate. In Figure 3-2, Configuration 2, the STP path for Bridge C travels through Bridge A.

Maximizing DLS Potential

Figure 3-4 illustrates one way to change the Figure 3-2 configurations to create DLS Networks.

In both Configuration 1 and 2 above, Bridge B was reconfigured to become the Root. This allows Network A-C to become a DLS path in both configurations (i.e. in configuration 1, Network A-C is no longer connected to the Root and in both Configuration 1 and 2, the STP path to the root for either Bridge A or Bridge C does not travel through the other).

While this change to Configuration 1 has no bad side effects, the same may not be true for Configuration 2. The entire configuration must be analyzed to insure that moving the Root to Bridge A does not cause loss of DLS paths in the Remote Sites. Also, the likelihood of role reversals in the case of Root failure has to be analyzed.

Figure 3-4 illustrates another way to change the Figure 3-2 configurations to create DLS paths.

In both configuration 1 and 2 in Fig. 3-5, the Network Cost of Network A-C was reduced enough to allow Network A-C to become the STP path for Bridge C. This allows Network B-C to become a DLS path in both configurations (i.e. in Configuration 1, Network B-C is not connected to the Root and in both Configuration 1 and 2, the STP path to the root for either Bridge B or Bridge C does not travel through the other).

While this change to Configuration 1 may have been more difficult to determine than changing the Root Bridge, in Configuration 2 it may be justified because it avoids the potential problems associated with moving the Root.

In Figure 3-6 the sectors and sub-sectors associated with configuration 2 in Figure 3-5 are illustrated. In Figure 3-6, the Root Bridge, Bridge D, is placed in the center of the configuration and its networks that are used as part of the STP paths form sectors 1-4. Bridge A is placed in the sector 3 and Bridge B in sector 3-2. So far the illustration is the same as in Figure 3-3. However, in Figure 3-6, Bridge C is placed in sector 3-3 because Network A-C is now part of Bridge C's STP path.

In Figure 3-6 Backup Network B-C is drawn (the dotted line) between the sectors 3-2 and 3-3. Since the dotted line is not pointed to/from the Root (as it is for Network A-C in Figure 3-3), Network B-C can be used

as a DLS path.

As in Figure 3-3, the direction of the dotted line for Network B-C can be determined by analyzing the Sector ID's associated with the end-points. Network B-C's Sector IDs equal 3-2 and 3-3. Since neither is completely contained within the other, Network B-C does not point to/from the Root.

Tandem DLS Paths

As mentioned in Section 1, DLS Paths can be concatenated together in tandem. Figure 3-7 illustrates that the Figure 3-1 configuration contains a second DLS path, Network C-G.

Once DLS paths B-C and C-G are operational, Tandem network path B-C-G will be discovered by Bridge B and Bridge G. This means that both Bridges can use DLS paths to communicate with both

1. stations located further away from the Root than Bridge C (i.e. stations located on Bridge C's Ethernet and across Network C-E);
2. stations located further away from the Root than the other Bridge (i.e. for Bridge B, stations located on Bridge G's Ethernet and for Bridge G stations located on Bridge B's Ethernet and across Network B-D).

Figure 3-8 illustrates TransLAN view of the Figure 3-7. TransLAN sees three separate DLS paths, path B-C, path C-G and path B-C-G. Tandem DLS path B-C-G is evaluated just like path B-C and C-G. For example, if Force DLS is not equal to True for Network B-C in Bridge B or Network G-C in G above, the **Network Cost** of DLS path B-C-G is compared against the STP cost of path B-A-G. If the Network Cost of B-C-G is not less, B-C-G is not used as a DLS path.

Also, for example, the **Sector IDs** of path B-C-G endpoint Bridges are analyzed. As illustrated, since Bridge B has a **Sector ID** of 4 and Bridge G a **Sector ID** of 2, path B-C-G is a valid DLS path (i.e. B's STP path to the Root does not intersect G or vice versa).

Figure 3-9 below illustrates how the Figure 3-8 configuration can be expanded by adding one site and two Networks. The addition of Bridge H, Network B-H and E-H results in E-H becoming a DLS path (**Sector ID** 3-2 is not contained in 4-3 or vice versa.)

Remember, however, DLS path E-H is used only for communication between stations on H's and E's Ethernet. For example, Bridge C Ethernet Stations can not use STP path C-E and DLS path E-H to communicate with H's Ethernet stations. They must communicate with H's Ethernet stations either across STP path C-A-B-H or across DLS path C-B and STP path B-H.

As stated earlier, once the DLS paths are discovered, the endpoint bridges begin to periodically advertise stations addresses that can be switched to the DLS Networks. Only a few addresses are advertised at a time and are advertised in the DLS frames. The DLS frames also contain the STP **Network Cost** of the DLS path.

For example, in Figure 3-9, Bridge B transmits a DLS frame across Network B-C once every **DLS Interval**. The frame contains a few addresses of stations located on B's Ethernet or across Network B-D and the **Network Cost** of Network B-C. Bridge C both processes the DLS frame and forwards it across Network C-G to Bridge G for processing. The **Network Cost** in the forwarded frame is incremented by Network C-G's **Network Cost**. This DLS frame generation, processing, and forwarding allows both Bridge C and G to receive the necessary information from Bridge B to switch addresses from their STP paths to DLS path C-B and G-C-B, respectively. The switching of these addresses is discussed next.

Switching Addresses to/from DLS Paths

Figure 3-10 assigns for convenience stations 0-9 to Bridge G's Ethernet, stations 10-19 to Bridge C's Ethernet, stations 20-29 to Bridge E's Ethernet, stations 30-39 to Bridge H's Ethernet, and stations 40-49 to Bridge B's Ethernet.

Initially, all remove communication between Ethernet stations 0-9 and all other stations and stations 10-29 and 30-49 is tandem switched through Bridge A, the Root bridge (e.g. this communication uses the STP paths). As discussed above, once the DLS paths are discovered (i.e. B-C, C-G, B-C-G, and E-H), the Bridges supporting the DLS path endpoints begin advertising stations addresses to be switched.

When Bridge C advertises to Bridge B that station 10 can be switched to DLS path B-C, Bridge B determines if the switch can be made. Normally, if Bridge B has set Network B-C's **Current State** equal DLS Forwarding or DLS Backup and B-C's **FDSE Maximum** does not equal **FDSE Total** (assuming B-C's **Force DLS** = True) the switch is made.

However, if Bridge B were to immediately switch 10's FDSE Source Network to B-C, FIFO could be lost. Frames destined for 10 could be traveling across STP path B-A-C while a later frame destined for 10 could take the B-C path and reach station 10 first.

First the Source Network in 10's FDSE is set equal to Network B-C. If Bridge B's **FIFO Required** equals False, processing is complete. Otherwise, the potential loss of FIFO is avoided by Bridge B by also setting **Do Not Forward** equal to True in 10's FDSE. Then if Bridge B's **Transmit Flush Frame** equals True, Bridge B then generates a Flush frame addressed to Bridge C and sends it across the STP path through the Root to Bridge C (i.e. path B-A-C); Bridge C then sends it back to B along DLS path C-B. When the Flush frame is received by Bridge B, it sets **Do Not Forward** equal to False in 10's FDSE.

The elapsed time while the Flush frame is on its round trip journey should normally be 1-2 seconds with a worst case time for the configuration equaling **DLS Round Trip Delay.** Communication to station 10 from B's Ethernet and Network B-D and B-H is temporarily halted while the Flush Frame is on its round trip journey. If the Flush Frame is lost or **Transmit Flush Frame** equals False, Bridge B sets **Do Not Forward** back to False in 10's FDSE after waiting for a time period equal to **DLS Round Trip Delay.**

In summary, when multiple addresses are advertised by Bridge C and switched at the same time by Bridge B, a single Flush frame is generated by B and remains intact throughout its round trip journey. This may not be the case when multiple addresses are advertised by E and switched by Bridge H (assuming both **FIFO Required** and **Transmit Flush Frame** equals True in H).

In the later case, the challenge is to insure that an address's path is really flushed before setting **Do Not Forward** equal to True in its FDSE. To insure this occurs, Bridge H started the round trip generating a Flush frame addressed to Bridge B (i.e. not E) and sending it down Network H-B. However, unlike B's case above, the frame can not be sent directly across the STP path through the Root to E (i.e. path H-B-A-C-E) because Bridge B supports a DLS path and is located between Bridge H and the Root. Consequently, Bridge H addresses the Flush frame to the **Next DLS Bridge** along the **Inlink** path to the Root.

When Bridge B receives H's Flush frame, it examines its addresses. If any of the Flush addresses match an FDSE with a Source Network equal to DLS Network B-C (termed DLS addresses), the original Flush frame must be split into two frames, one containing the DLS addresses and one the non-DLS addresses. The Flush frame with the DLS addresses is sent to across the DLS path to Bridge C, the next DLS Bridge along the DLS path. Because there is no **Next DLS Bridge** between Bridge B and the STP path to the Root, the Flush frame with the non-DLS addresses is sent directly to Bridge E across path B-A-C-E.

When Bridge C processes the Flush frame with the DLS addresses, it sends it to Bridge E across Network C-E. This is done because Bridge E is further away from the Root than Bridge C and E's STP path to the Root passes through C.

When Bridge E receives either the Flush frames with the DLS or non-DLS addresses, it sends it directly to Bridge H across Network E-H. When either of the Flush frames are received by Bridge H, it sets **Do Not Forward** equal to False in the FDSE(s) whose addresses are associated with the Flush frame.

If stations 30-39 and 20-29 could utilize even more STP/DLS paths for communication, potentially the Flush frame would be split even further in the same fashion. In fact, if there are enough utilized paths, the splitting could continue until each Flush frame contains only one address. Of course, even if there are enough utilized paths, it is very unlikely that this level of splitting will be required for a given set of addresses.

The same sequence of events occur when due to aging an FDSE is switched back to a STP path. First the Source Network in the FDSE is set equal to network associated with the STP path. If **FIFO Required** equals False, processing is complete. Otherwise, the potential loss of FIFO is avoided by setting **Do Not Forward** equals to True in the FDSE, and, if **Transmit Flush Frame** equals True, transmitting a Flush frame. Then, when the Flush frame is received or the **DLS Round Trip Delay** interval expires, **Do not Forward** is set back to False in the FDSE.

Forwarding of Frames to/from DLS Paths

Once Bridge C in Figure 3-10 switches station addresses 40-49 to DLS path C-B, if a single destination frame is received from C's Ethernet, Network C-E or C-G and is destined to station 40, it will be forwarded to Network. C-B. If a frame is received from Network C-A, the Inlink, and is destined to 40, it is not forwarded.

The frame received from Network C-A is discarded, because it will only be received across C-A as long as Bridge A views 40 as an unknown single destination (or 40 moves or STP changes the configuration,

both of these conditions are discussed later). In addition, as long as Bridge A has this unknown single destination perspective, there is a duplicate frame that reaches 40 using a STP path (e.g. Bridge A will also transmit a copy on Network A-B, if the frame is received from A's Ethernet, Network A-F or A-G). When 40 becomes a known single destination to Bridge A, Bridge C will no longer receive these frames on Network C-A (i.e. Bridge A will know to only forward frames destined to 40 to Network A-B and not also to A-C).

Also, relative to receiving frames from Network C-B, Bridge C only forwards known single destination frames. One should note that these frames are only forwarded by Bridge C to its Ethernet, Network C-E, or C-G. This is because the only addresses advertised as DLS candidates to Bridge B are those which lie in these directions. Bridge C discards unknown single destination frames received from Network C-B.

As impled above, multicast destination frames are not transmitted on DLS paths. They are only transmitted across STP paths.

DLS FDSE Aging

As discussed above, assigning DLS Source Networks to FDSEs (termed DLS FDSEs) is done differently than assigning non-DLS Source Networks to FDSES. FDSE are initially assigned to DLS paths based upon address information advertised within DLS frames, not based upon source addresses in received frames. Also, a Source Network value is not changed in a DLS FDSE when the matching Source Addresses value is received from an STP path (e.g. from a multicast frame).

This change in learning also impacts the Aging of DLS FDSEs. This impact must be handled carefully because FDSE Aging is the mechanism used to handle station movement and STP path changes (when STP activates a new STP path, Short Aging Timers are run in all Bridges, expediting the aging off of FDSEs associated with inactive addresses).

In Bridge B, Figure 3-10, when Short Aging Timers are not running, the Aging value in one of its DLS FDSE's, for example 10's FDSE, can be sent to Young by two events. It is set to Young when the address value of 10 is received from Network B-C in either a frame's source address or as a value within Bridge C's DLS frame. When Short Aging Timers are running, the Aging value in 10's FDSE is only set to Young when the address value of 10 is received from Network B-C in a frame's source address. Independent of Short Aging timers, 10's FDSE Aging value is not impacted by frames received from other than Network B-C.

DLS Interaction with STP

In Figure 3-10, if Bridge G's Inlink (i.e. Network G-A) fails, G sets Network G-A's **Current State** equal to Broken. From this point on the processing in both Bridge G and C is dependent upon the value of Network G-C's **Current State.** Note that if Network G-C's **Current State** in Bridge G equals DLS Backup, Network C-G's **Current State** in Bridge C equals DLS Forwarding and vice versa.

In Network G-C's **Current State** equals DLS Backup, Bridge G determines instantly G-C is its new Inlink. As a result, Bridge G sets Network G-C's **Current State** equal to Pre-Forwarding 2 and stops generating any DLS frames across Network G-C. In about 10 more seconds (**Pre-Forwarding Delay** ÷ 2), Bridge G changes Network G-C **Current State** to Forwarding and starts the running of Short Timers throughout the configuration. In about 10 more seconds (5 times the **DLS Interval - Pre-Forwarding Delay** ÷ 2), the absence of DLS frames causes Bridge C to change Network C-G'S **Current State** from DLS Forwarding to Forwarding. Network G-C is now a fully operational STP path.

If Network G-C's **Current State** equals DLS Forwarding, Bridge G temporarily assumes it is the Root, sets Network G-C's **Current State** equal to Forwarding, stops generating DLS frames, and begins to Transmit STP Hello frames on its Ethernet and Network G-C. As a result, in about 20 seconds (i.e. Bridge C's **Pre-Forwarding Delay**), Bridge C, relative to Network C-G, sets **Current State** equal to Pre-Forwarding 2, stops transmitting DLS frames, and starts transmitting STP Hello frames. Receipt of this Hello frame causes Bridge G to determine instantly that Network G-C is the new Inlink. In about 10 more seconds, Bridge C changes Network C-G **Current State** to Forwarding and starts the running of STP Short Timers throughout the configuration to age off outdated FDSEs. Network G-C is now a fully operational STP path.

In either of the above cases, the absence of any DLS frames from Bridge G also causes Bridge B to stop using DLS path B-C-G and the running of Short Timers in Bridge B causes it to age off stations 0-9 if they are idle. However, Bridge B will continue to use DLS path B-C for communication with 0-9. This is because as long as Network A-G is failed, Bridge C advertises addresses 0-9 in its DLS frames transmitted

on Network C-B (i.e. 0-9 are further away from the Root than C).

When Network A-G restores, the configuration returns to its original condition. Network G-A becomes Bridge G's Inlink, STP Short Timers are run throughout the configuration, and Network G-C initially becomes a STP Backup path. DLS path C-G and B-C-G are then rediscovered.

The results of other failures/restorals in Figure 3-10 are the same. In the case of failure, it takes the same amount of time to convert a DLS path to a STP path as it does to convert a STP Backup path to a STP path. In the case of restorals first STP paths and Backup paths are reestablished and then the DLS paths are reestablished.

DLS Extensions

Figure 3-11 contains an example of how the Figure 3-10 configuration could be modified to require the DLS Extension feature.

In Figure 3-11, Bridges G′ and H′ have been added and interface directly to the DLS paths and have Ethernet Inlinks. The DLS Extension feature is invoked by setting **Enable DLS** equal true for the Bridge G and H Ethernet Transmit Network (G and H are the DB's for their respective Ethernets). Of course, **Enable DLS** must also be set to true for the DLS path Transmit Networks in both Bridge G′ and H′. If this is done, all of the DLS capabilities associated with the configuration in Figure 3-10 now apply to the configuration in Figure 3-11.

In Figure 3-11 Bridge H generates the DLS frames instead of H′ and transmits them on its local LAN. The addresses in the DLS frames are addresses H Believes are on its local LAN. Bridge H′ receives the DLS frames, deletes any addresses it knows are not on the local LAN and forwards the DLS frames onto Bridge E. Bridge E processes the DLS frames as described earlier. Likewise, Bridge H′ processes E's DLS frames as described earlier and then forwards them on to H. H makes the FDSEs associated with all the addresses received in DLS frames as "do not forward".

While I have illustrated and described the preferred embodiments of my invention, it is to be understood that these are capable of variation and modification, and I therefore do not wish to be limited to the precise details set forth, but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

Claims

1. A method of exchanging frames between bridges to distribute load sharing in a communications network of the kind in which bridges, and related stations in local LANs, e.g. Ethernet LANs and 802 LANs, can be linked by paths in a plurality of sub-networks and wherein the bridges are linked to support a Spanning Tree Protocol (STP) which elects one bridge as a root and then, with respect to said root, computes and utilizes one and only one loop free set of primary paths between all bridges, said method comprising,
examining remaining paths, i.e. paths other than said STP primary paths, between the bridges as possible sub-network paths for a Distributed Load Sharing (DLS) configuration in which frames exchanged between certain stations can utilize more than said STP one set of primary paths between the stations,
selecting certain ones of the remaining paths as DLS paths only when
(a) the two bridges interfacing to the DLS path also interface to one or more other sub-networks and neither is the STP root bridge, and
routing over a selected DLS path only those frames

(a) which have a known single destination, and

(b) which are frames to be transferred between stations (1) which are further away from the root than either bridge associated with said stations of (2) which lie on the bridge's local LAN.

2. The invention defined in claim 1 including configuring the bridges at the ends of a DLS path to know which stations are farther away from said root so that frames are not transferred between stations whose source network is an STP inlink on either bridge unless the STP inlink on either bridge is the local LAN.

3. The invention defined in claim 1 including switching station addresses between an STP path and selected DLS paths and preserving first-in first-out (FIFO) frame exchange while switching said station addresses.

4. The invention defined in claim 1 including supporting tandem DLS paths made up of shorter DLS paths.

5. The invention defined in claim 1 wherein each DLS path bridge is a self learning bridge.

6. The invention defined in claim 5 including configuring self learning bridges on a potential DLS path (a) to recognize when said bridges are on a potential DLS path, (b) to let the related bridge on the DLS path know of said recognition, (c) to decide whether the related bridge is on the DLS path, (d) to agree with the related bridge to form the DLS path, (e) to advertise to the related bridge which stations are appropriate to use the DLS path, (f) to flush the STP path with a flush packet prior to switching stations over to start using the DLS path to thereby preserve first-in first-out (FIFO) frame exchange between stations, then (g) to start switching stations over to using the DLS path.

7. The invention defined in claim 6 including performing steps (f) and (g) in reverse prior to switching a DLS path over to an STP path.

8. The invention defined in claim 5 wherein each bridge on a DLS path has either (1) a first port for association with an STP path pointing to said root, at least a second port for association with an STP path pointing away from said root, and a third port for association with the DLS path or (2) a first port for association with an STP path pointing to said root and only a second port for association with the DLS path.

9. The invention defined in claim 5 including configuring the bridges to remain compatible with STP while establishing a DLS path.

10. The invention defined in claim 1 including configuring the data stores for each of the sub-networks for operation with STP and DLS paths.

11. Apparatus for exchanging frames between bridges to distribute load sharing in a communications network of the kind in which bridges, and related stations in local LANs, e.g. Ethernet LANs and 802 LANs, can be linked by paths in a plurality of sub-networks and wherein the bridges are linked to support a Spanning Tree Protocol (STP) which elects one bridge as a root and then, with respect to said root, computers and utilizes one and only one loop free set of primary paths between all bridges, said apparatus comprising,
self learning bridge means for examining remaining paths, i.e. paths other than said STP primary paths, between the bridges as possible sub-network paths for a Distributed Load Sharing (DLS) configuration in which frames exchanged between certain stations can utilize more than said STP one set of primary paths between the stations,
said self learning bridge means also including DLS path selecting means for selecting certain ones of the remaining paths as DLS paths only when
(a) the two bridges interfacing to the DLS path also interface to one or more other sub-networks and neither is the STP root bridge,
and for routing over a selected DLS path only those frames
(a) which have a known single destination, and
(b) which are frames to be transferred between stations (1) which are further away from the root than either bridge associated with said stations or (2) which lie on the bridge's local LAN.

12. The invention defined in claim 11 wherein said self learning bridge means include bridges having either (1) a first port for association with an STP path pointing to said root, at least a second port for association with an STP path pointing away from said root, and a third port for association with the DLS path or (2) a first port for association with an STP port pointing to said root and only a second port for association with the DLS path.

13. The invention defined in claim 11 wherein the self learning bridge means include configuration means for configuring the bridges at the ends of a DLS path to know which stations are farther away from said root so that frames are not transferred between stations whose source network is an STP inlink on either bridge unless the STP inlink on either bridge is the local LAN.

14. The invention defined in claim 13 wherein the configuration means configure the bridges to remain compatible with STP while establishing a DLS path.

15. The invention defined in claim 13 wherein the configuration means configure the data stores for each of the sub-networks for operation with STP and DLS paths.

16. The invention defined in claim 11 wherein the self learning bridge means include cost determining means for optionally using cost information learned from STP to identify which sub-networks of STP are both STP backup networks and DLS paths and for utilizing such STP backup networks as DLS paths.

17. The invention defined in claim 11 wherein the self learning bridge means include switching means for switching station addresses between an STP path and selected DLS paths and flushing means for flushing the DLS paths with a flush packet prior to switching station addresses to preserve first-in first-out (FIFO) frame exchange while switching said station addresses.

18. The invention defined in claim 11 wherein the self learning bridge means include tandem path support means for supporting tandem DLS paths made up of shorter DLS paths.

19. The invention defined in claim 13 wherein the configuration means are constructed (a) to recognize when said bridges are on a potential DLS path, (b) to let the related bridge on the DLS path know of said recognition, (c) to decide whether the related bridge is on the DLS path, (d) to agree with the related bridge to form the DLS path, (e) to advertise to the related bridge which stations are appropriate to use the DLS path, (f) to flush the STP path with a flush packet prior to switching stations over to start using the DLS path to thereby preserve first-in first-out (FIFO) frame exchange between stations, then (g) to start switching stations over to using the DLS path.

20. The invention defined in claim 19 wherein the configuration means are constructed to perform steps (f) and (g) in reverse prior to switching a DLS path over to an STP path.

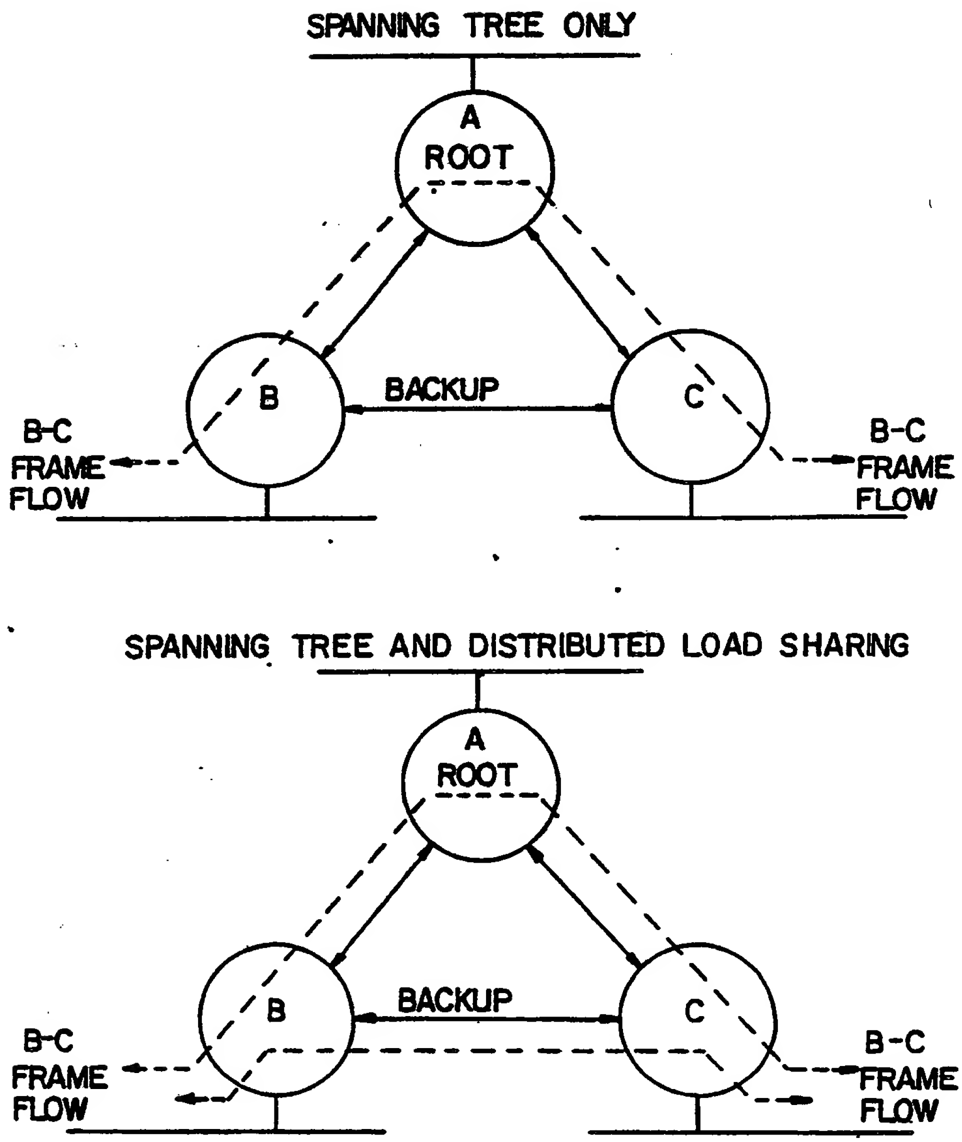

SPANNING TREE ONLY
A
ROOT
B
C
BACKUP
B-C
FRAME
FLOW
B-C
FRAME
FLOW
SPANNING TREE AND DISTRIBUTED LOAD SHARING
A
ROOT
B
C
BACKUP
B-C
FRAME
FLOW
B-C
FRAME
FLOW

FIG.1

FRAME EXCHANGES IMPACTED BY DLS IN AN EXPANDED CONFIGURATION

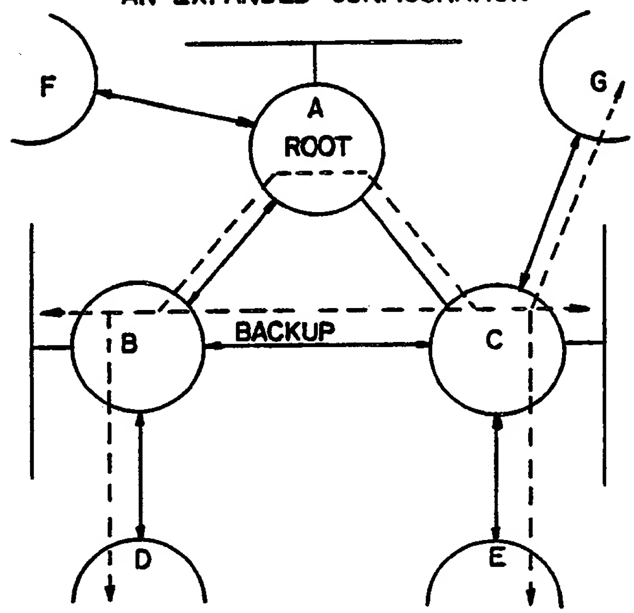


FIG.2

FRAME EXCHANGES NOT IMPACTED BY DLS IN AN EXPANDED CONFIGURATION

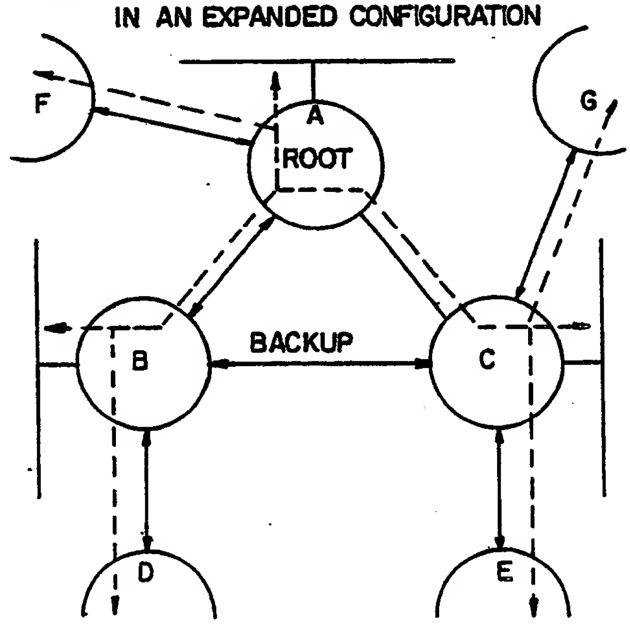


FIG.3

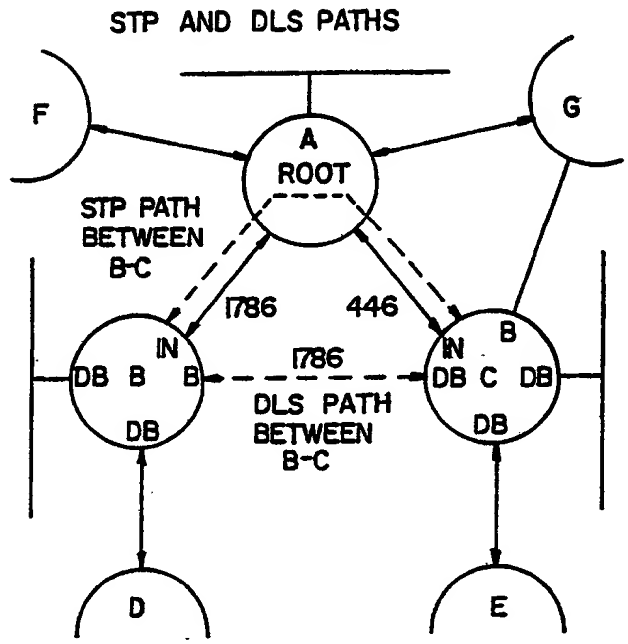
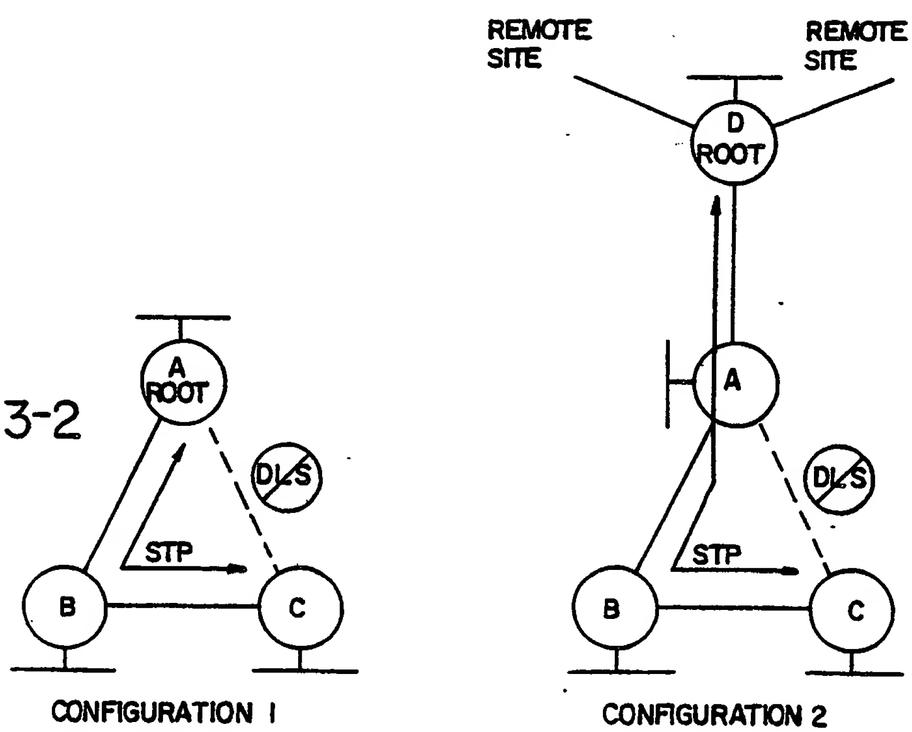

STP AND DLS PATHS
F
G
A
ROOT
STP PATH
BETWEEN
B-C
1786
446
IN
DB
B
DB
C
DLS PATH
BETWEEN
B-C
D
E

FIG. 3-1

FIG. 3-2


A
ROOT
DLS
STP
B
C
CONFIGURATION 1
REMOTE SITE
REMOTE SITE
D
ROOT
A
DLS
STP
B
C
CONFIGURATION 2

Neu eingereicht / Newly filed
Nouvellement déposé

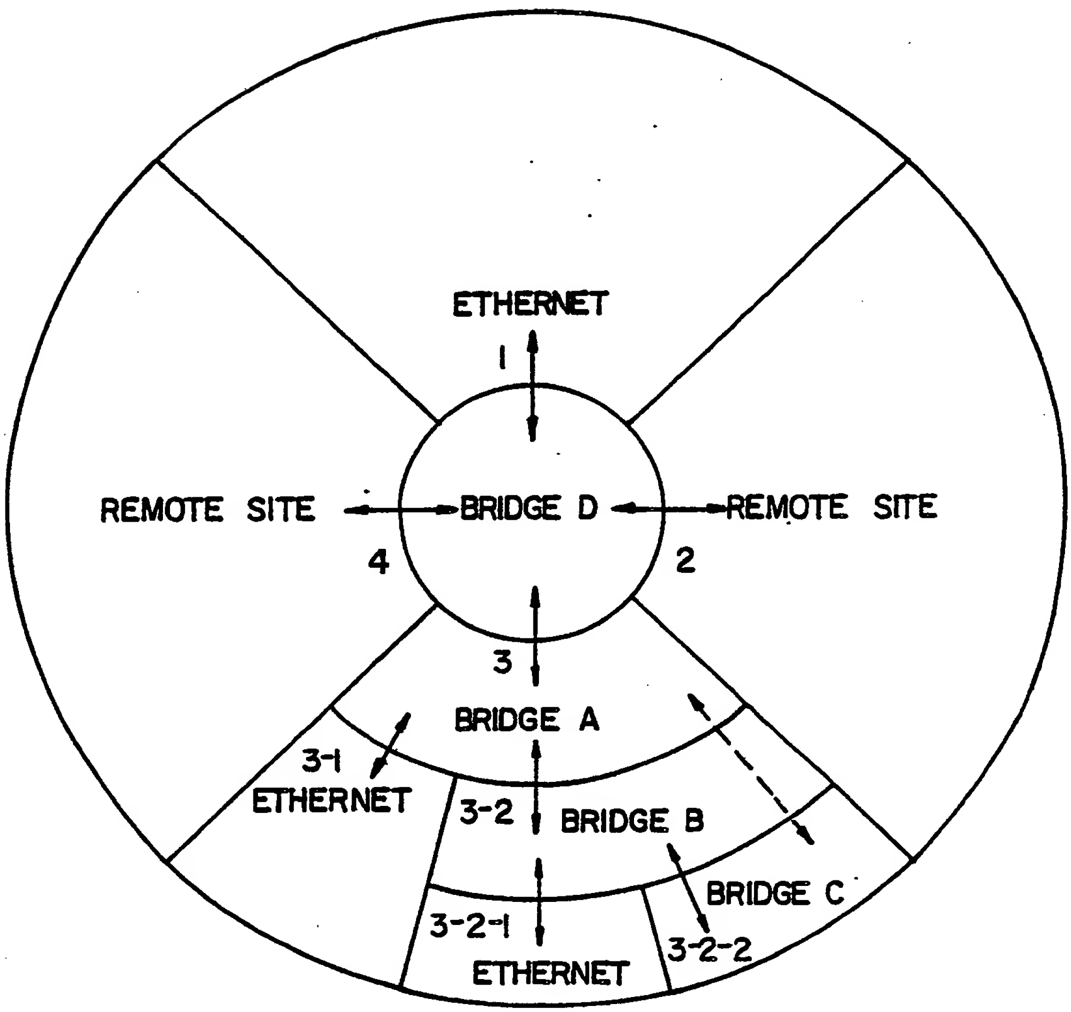


FIG. 3-3

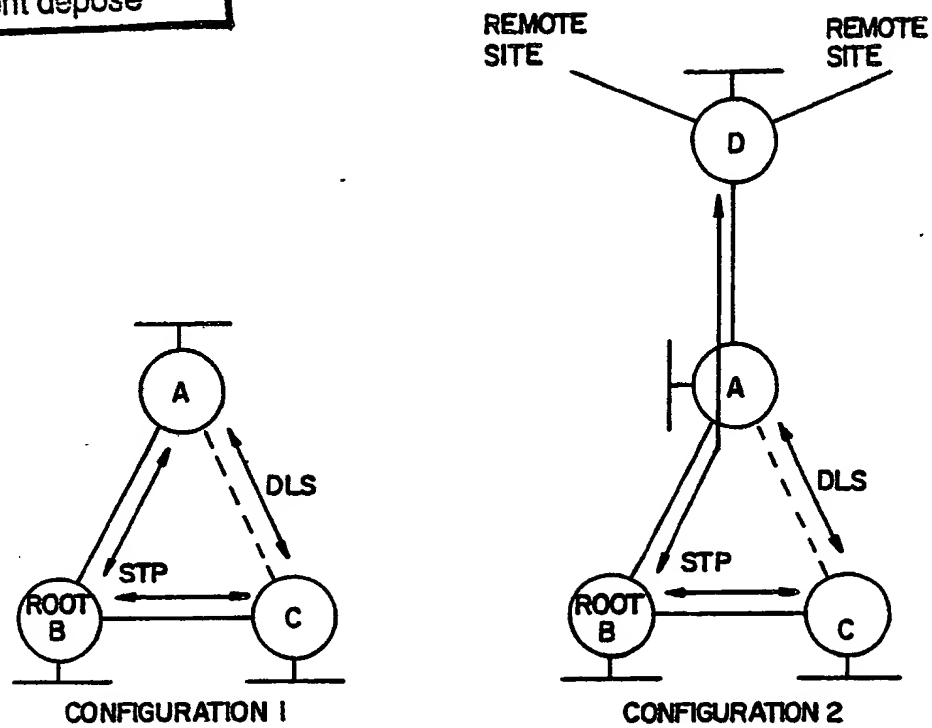

REMOTE SITE
REMOTE SITE
D
A
DLS
STP
ROOT B
C
CONFIGURATION 1
A
DLS
STP
ROOT B
C
CONFIGURATION 2

FIG.3-4

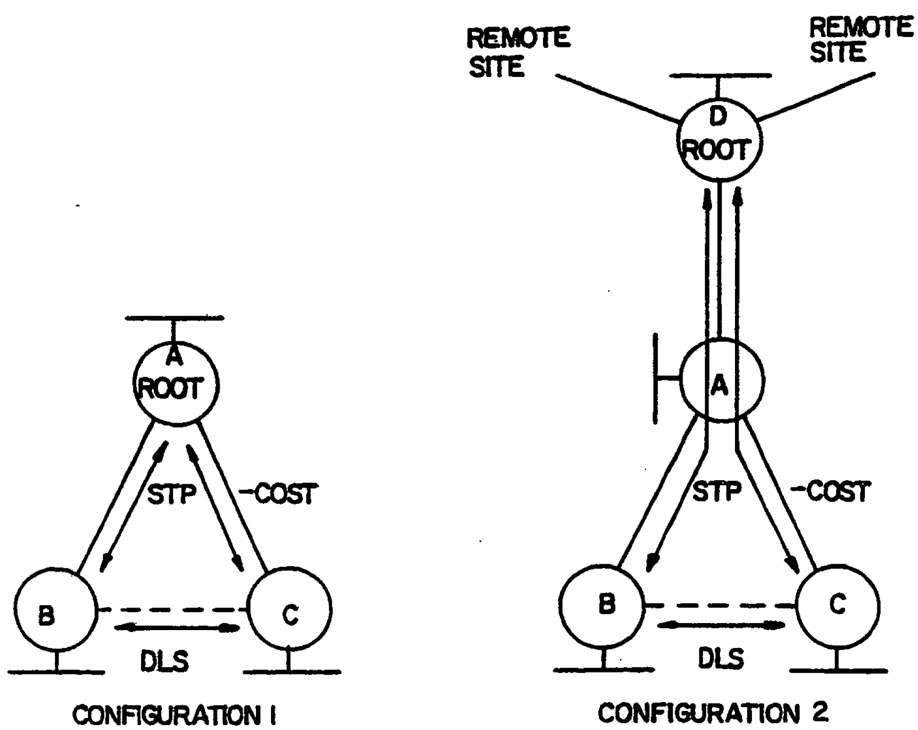

REMOTE SITE
REMOTE SITE
D ROOT
A ROOT
STP
-COST
B
C
DLS
CONFIGURATION 1
A
STP
-COST
B
C
DLS
CONFIGURATION 2

FIG.3-5

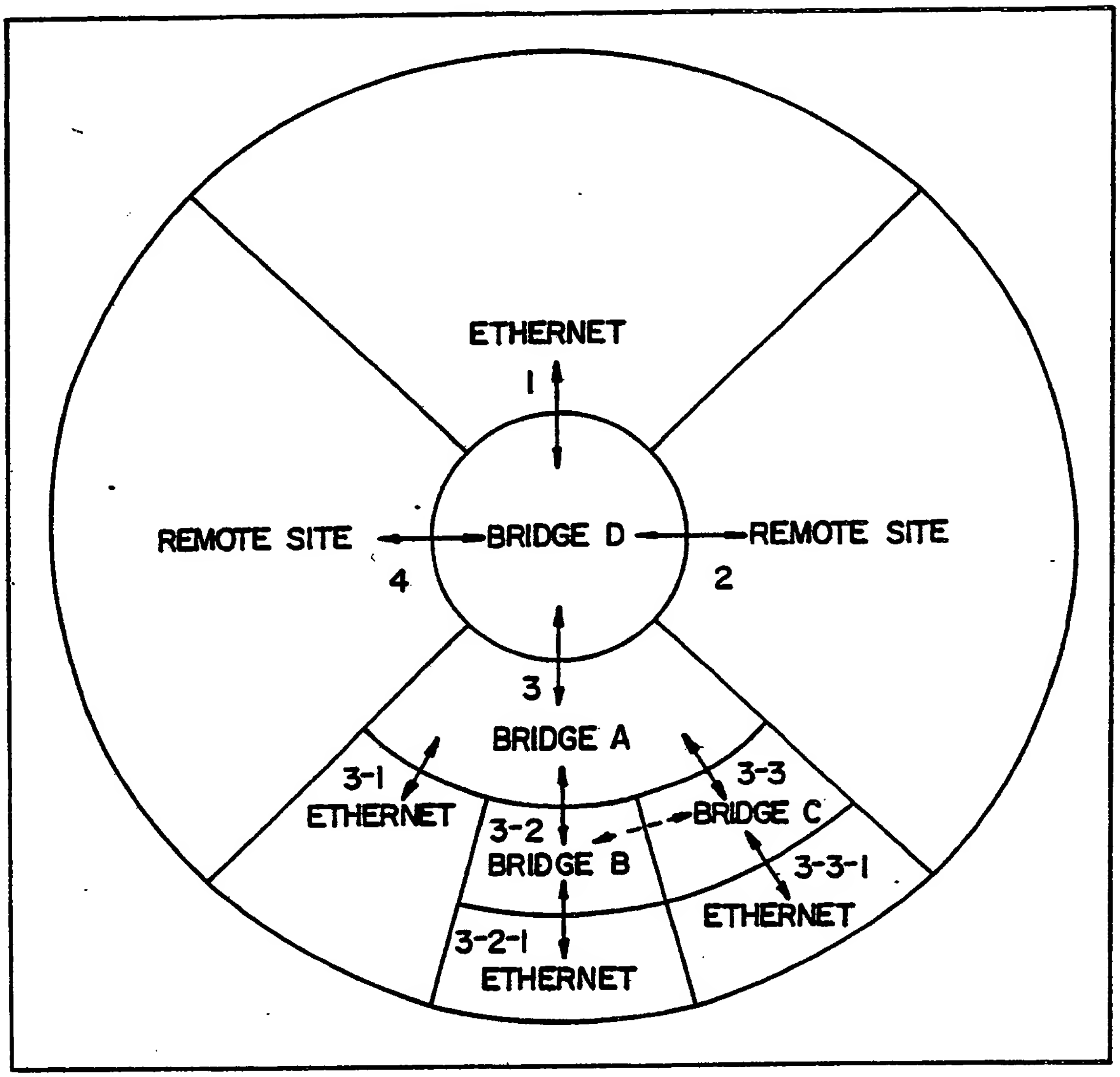

ETHERNET
1
REMOTE SITE
BRIDGE D
REMOTE SITE
4
2
3
BRIDGE A
3-1
ETHERNET
3-3
3-2
BRIDGE C
BRIDGE B
3-3-1
ETHERNET
3-2-1
ETHERNET

FIG. 3-6

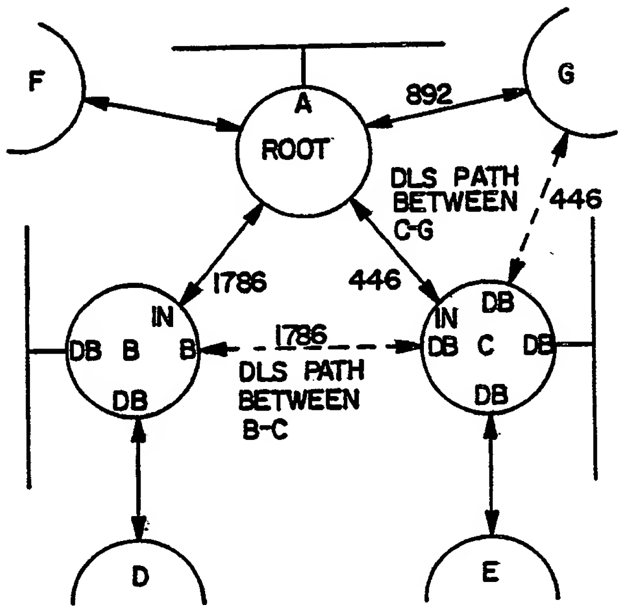

F
A
ROOT
892
G
DLS PATH
BETWEEN
C-G
446
1786
446
IN
DB B B
DB
1786
DLS PATH
BETWEEN
B-C
IN
DB
DB C DB
DB
D
E

FIG.3-7

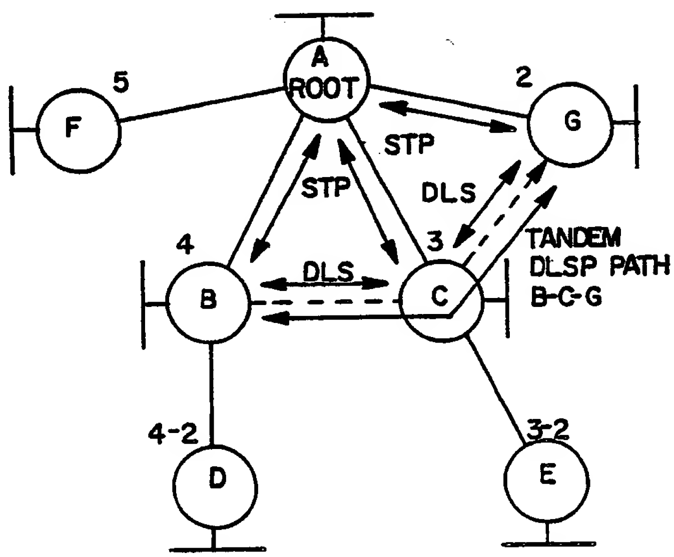

A
ROOT
5
F
2
G
STP
STP
DLS
4
3
TANDEM
DLSP PATH
B-C-G
B
DLS
C
4-2
D
3-2
E

FIG.3-8

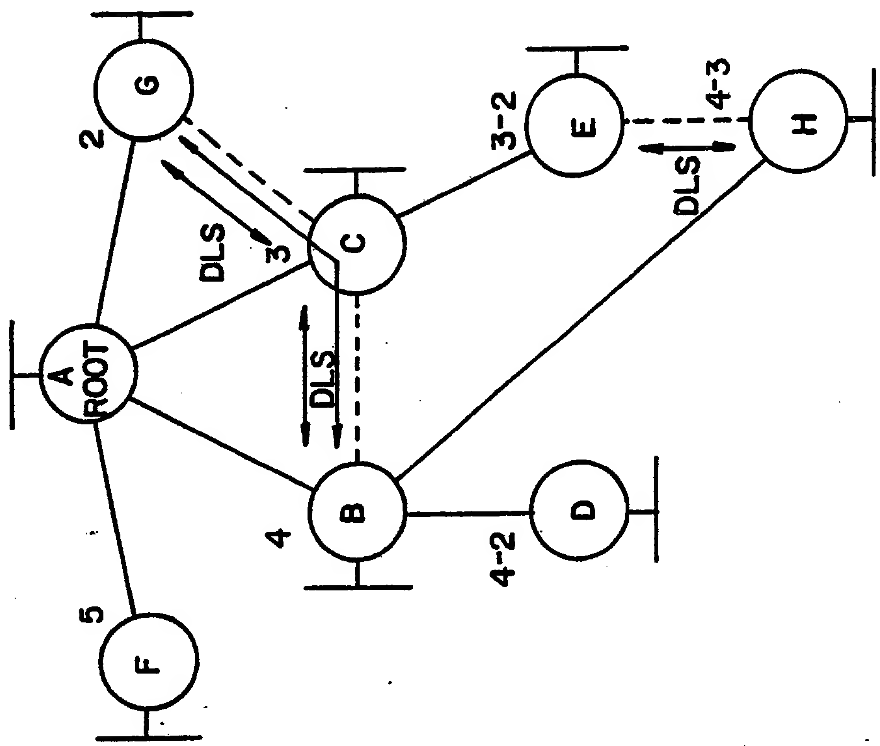


FIG.3-9

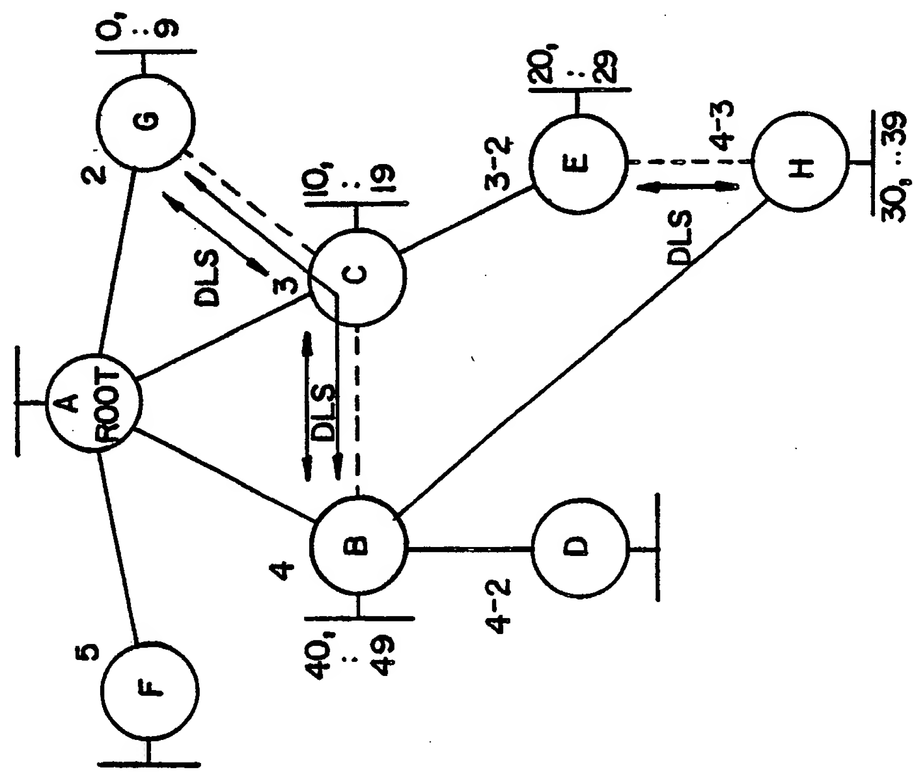


FIG.3-10

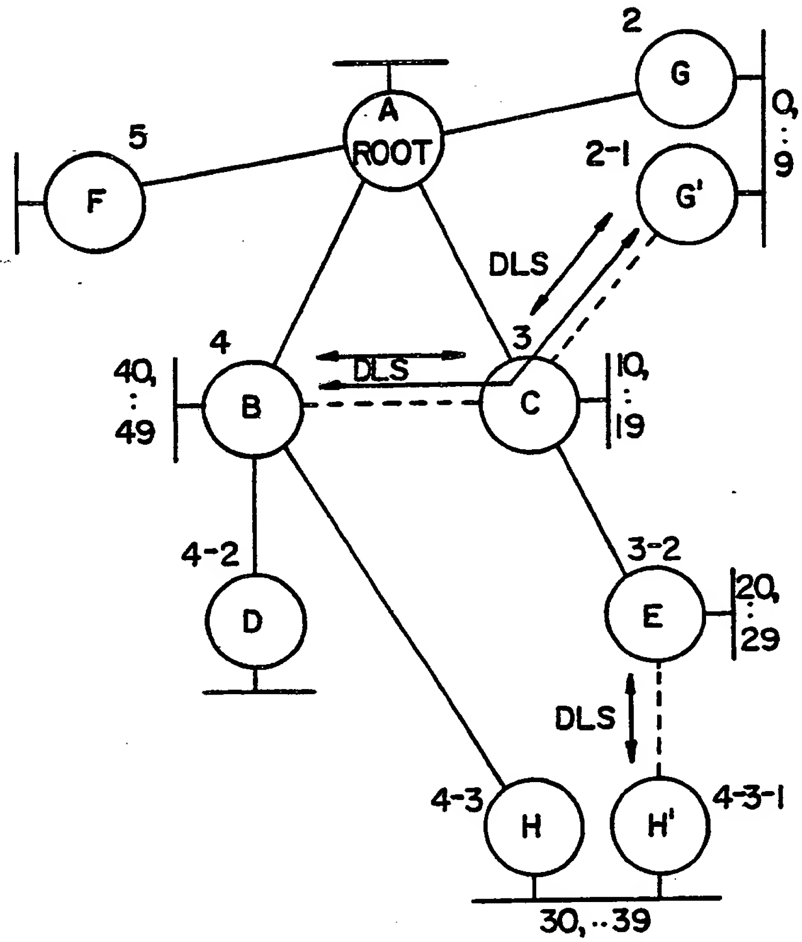

A
ROOT
F
5
G
2
G'
2-1
0,
:
9
DLS
DLS
3
C
10,
:
19
4
B
40,
:
49
4-2
D
3-2
E
20,
:
29
DLS
H
4-3
H'
4-3-1
30,..39

FIG.3-11

Neu eingereicht / Newly filed
Nouvellement déposé

FRAME EXCHANGES IMPACTED BY DLS IN A TANDEM DLS CONFIGURATION

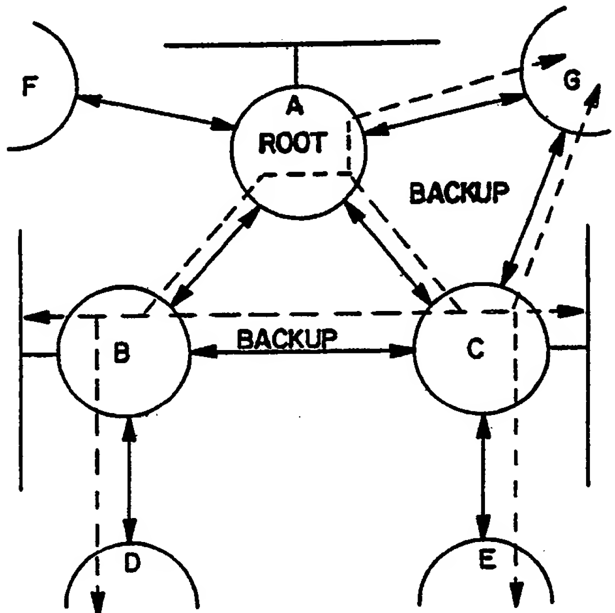


FIG.4

DLS ENDPOINT EXTENSION ACROSS ETHERNET

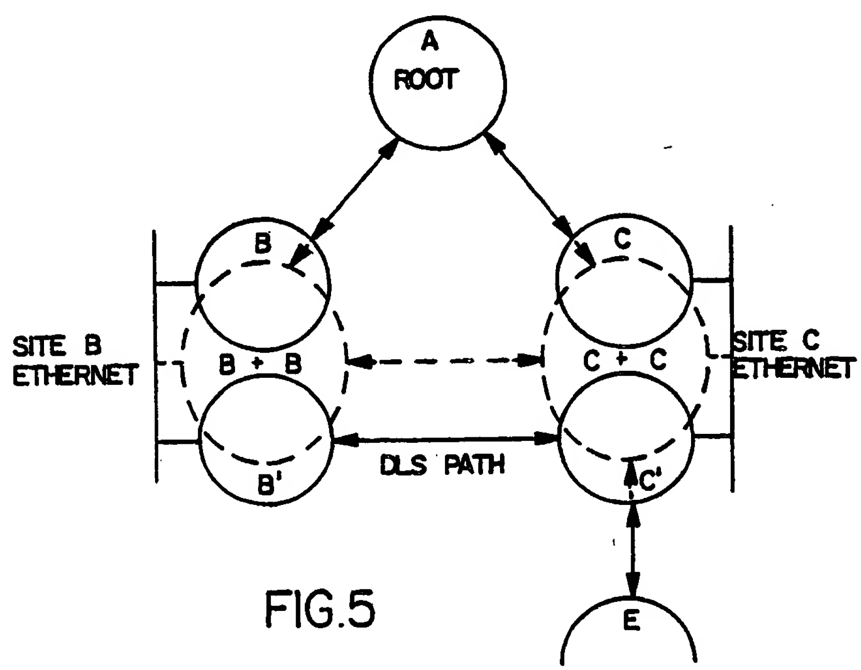
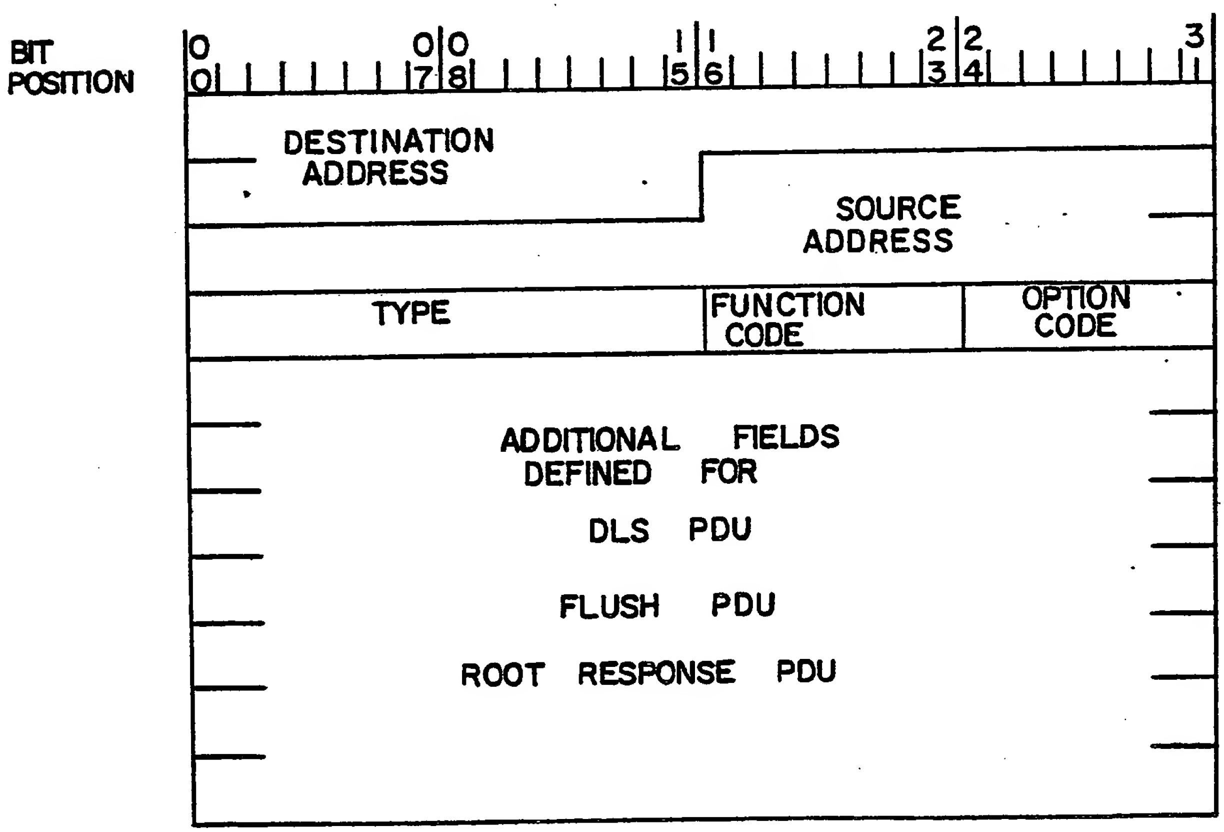


FIG.5

FIG.4 DLS PROTOCOL DATA UNITS (PDU)

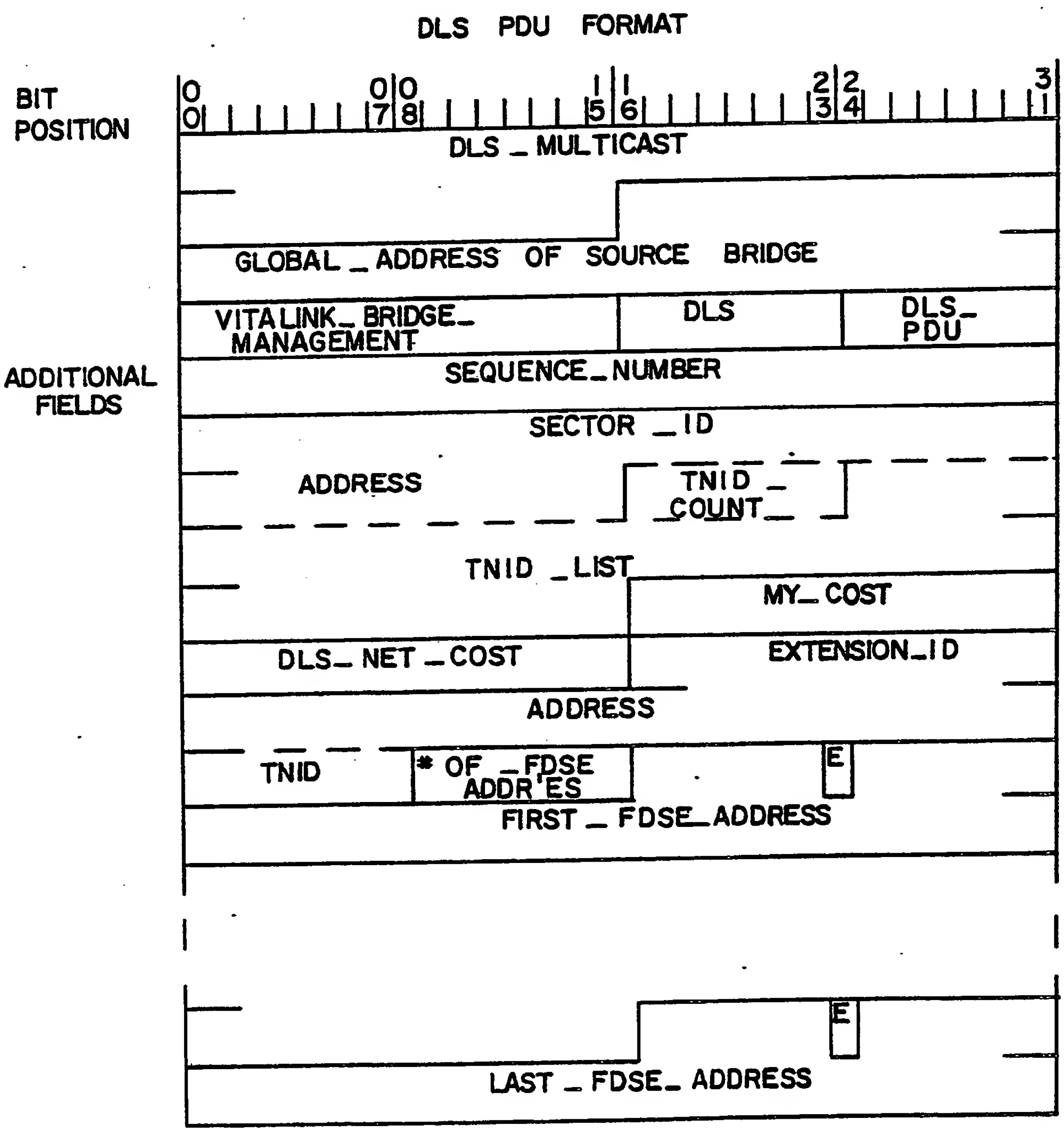
ALL THE DLS PDU's DEFINED IN THIS SECTION CONFORM TO THE GENERAL FORMAT ILLUSTRATED BELOW.

GENERAL FORMAT



Ingereicht / Newly filed
Nouvellement déposé

FIG. 4.1A DLS PROTOCOL DATA UNIT



SEQUENCE_NUMBER
CONTAINS A VALUE FROM 1-0xFFFFFFFF

SECTOR_ID
CONTAINS THE FOLLOWING FIELDS
ADDRESS=ROOT ADDRESS
TNID_COUNT=NUMBER OF TNID_LIST ENTRIES (1-7)
TNID_LIST=A STRING OF 1 OCTET TRANSMIT NETWORK ID (TNID) VALUES DEFINING THE PATH FROM THE ROOT. THE FIRST OCTET CONTAINS THE ROOT TNID,THE SECOND OCTET THE SECOND BRIDGE TNID,ETC.

MY_COST
EQUALS THE MY COST VALUE IN THE BRIDGE GENERATING THE DLS PDU

DLS_NET_COST
EQUALS THE NET_COST OF THE DLS PATH BETWEEN THE RECEIVING BRIDGE AND THE BRIDGE THAT GENERATED THE DLS PDU(e.g.,FOR TANDEM NETWORKS EQUALS THE SUM OF THE NET_COSTS OF EACH NETWORK ALONG THE DLS PATH).

EXTENSION_ID
CONTAINS EITHER ZERO OR THE FOLLOWING FIELDS
ADDRESS=ADDRESS OF THE BRIDGE INTERFACING TO THE EXTENDED DLS NETWORK
TNID=TNID OF THE EXTENDED DLS NETWORK

NUMBER_OF_FDSE_ADDRESSES
EQUALS THE NUMBER OF FDSE GLOBAL ADDRESSES IN THE DLS PDU. THE MAXIMUM NUMBER OF FDSE GLOBAL ADDRESSES A DLS PDU WILL CONTAIN IS EQUAL TO 216 (ASSUMING 8000 FDSE's AND AN 8 SECOND DLS_INTERVAL). SINCE 236 IS THE MAXIMUM NUMBER OF GLOBAL ADDRESSES THAT CAN BE CARRIED IN A 1518 OCTET DLS PDU,MULTIPLE PDU's WILL NEVER HAVE TO BE GENERATED DURING A DLS INTERVAL. IT SHOULD BE NOTED THAT DLS_INTERVALS WILL NORMALLY EQUAL 4 SECONDS AND IF A BRIDGE HAS 8000 FDES's ,108 IS THE MAXIMUM. VALUE;IF THE BRIDGE HAS 1000 FDES's,14 IS THE MAXIMUM. VALUE,ETC... HOWEVER,NORMALLY,A DLS PDU WILL CONTAIN FAR FEWER THAN THE MAXIMUM . FDSE GLOBAL ADDRESSES WITH ZERO BEING QUITE COMMON.

Nth_FDSE_ADRRESS
CONTAINS A SINGLE DESTINATION GLOBAL ADDRESS WHICH CAN BE SAFELY SWITCHED FROM THE STP PATH TO THE DLS PATH. SINCE A SINGLE DESTINATION ADDRESS ALWAYS CONTAINS 0 IN THE MULTICAST /BROADCAST BIT,THIS BIT CAN BE SAFELY USED AS A FLAG AS DEFINED BELOW

EMPTY FLAG (BIT 7 FOR 802.3)
0=FDSE GLOBAL ADDRESS CONTAINS A SINGLE DESTINATION GLOBAL ADDRESS
1=FDSE GLOBAL ADRRESS IS EMPTY (i.e.,DOES NOT CONTAIN A SINGLE DESTINATION GLOBAL ADDRESS

FIG 4.1B

FIG. 4.2 HELLO PROTOCOL DATA UNIT

HELLO PDU FORMAT.

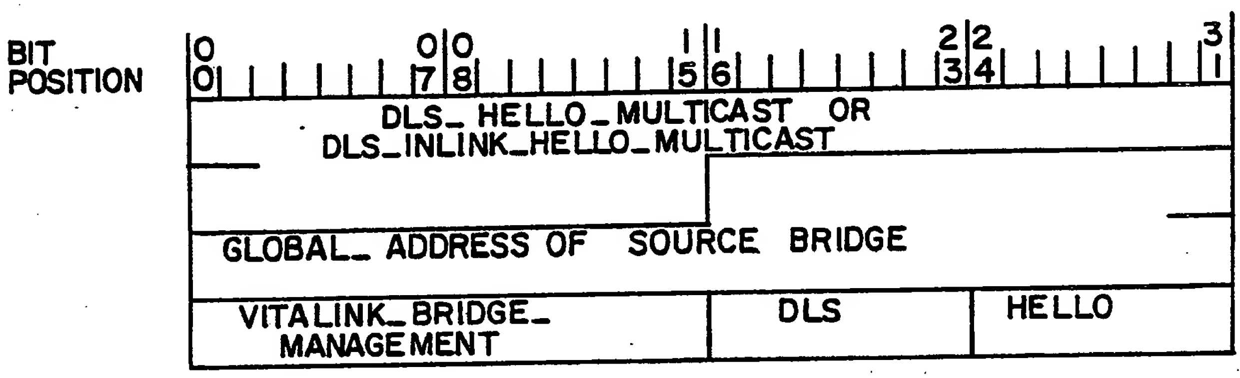
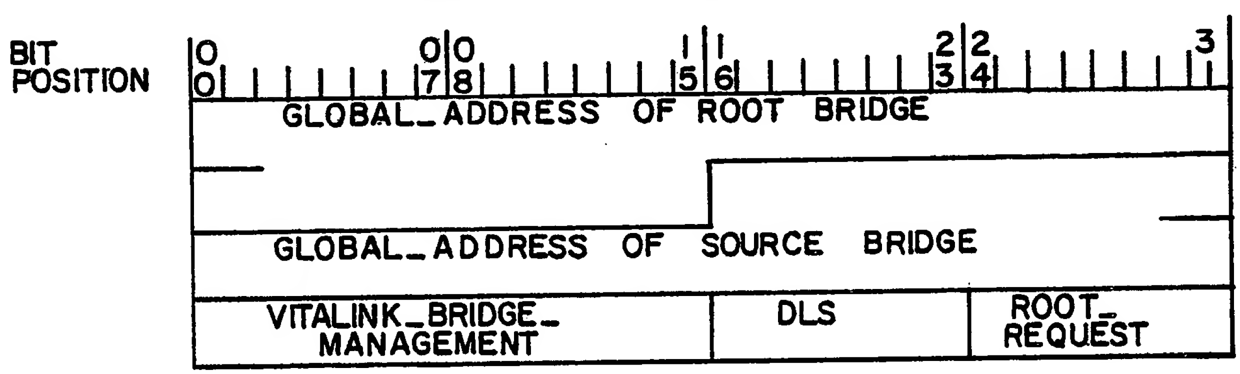


FIG. 4.4

ROOT REQUEST PROTOCOL DATA UNIT

ROOT REQUEST PDU FORM



FLUSH PROTOCOL DATA UNIT

FLUSH PDU FORMAT

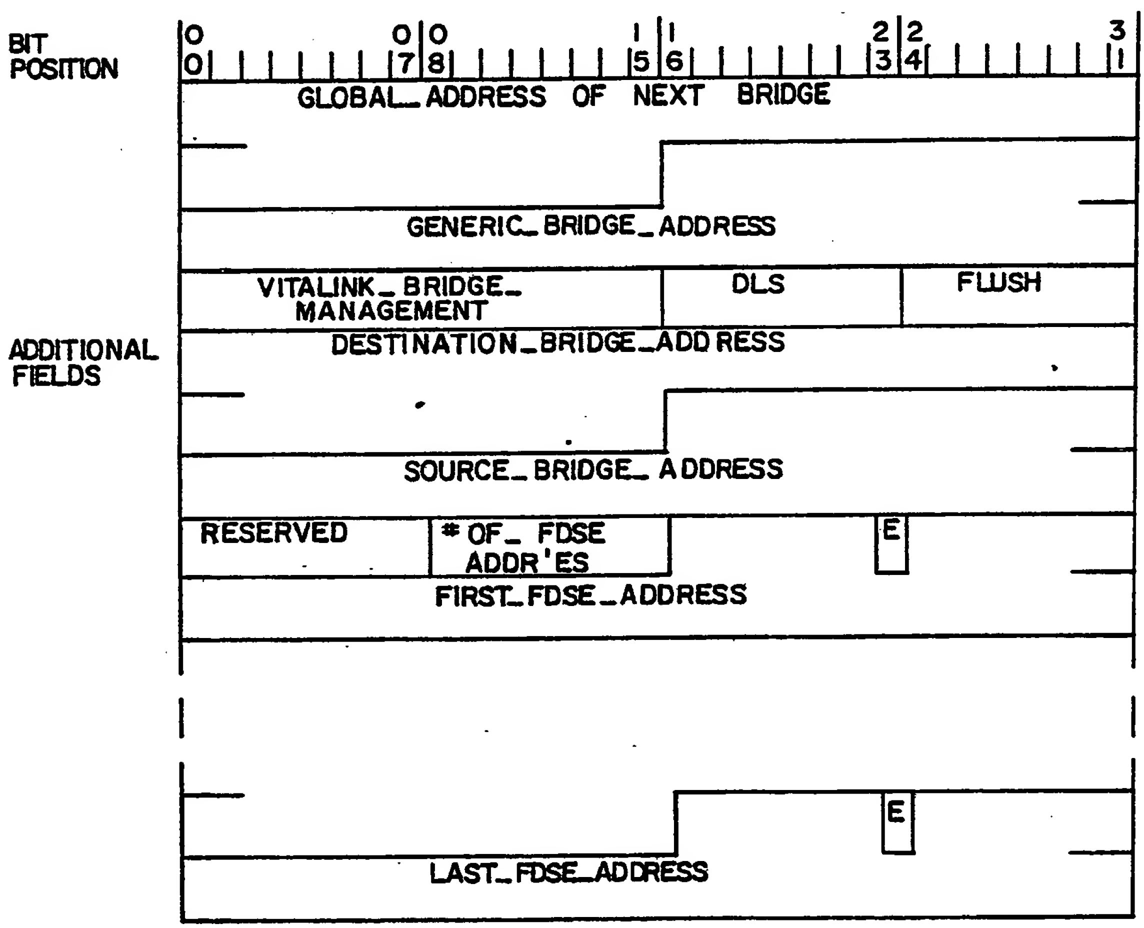


FIG. 4.3A

DESTINATION_BRIDGE_ADDRESS
EQUALS THE GLOBAL ADDRESS OF THE DLS BRIDGE TO WHICH THIS FLUSH PDU IS BEING SENT.. DEPENDING UPON THE CONFIGURATION THIS FIELD MAY NOT EQUAL THE DESTINATION_ADDRESS .

SOURCE_BRIDGE_ADDRESS
EQUALS THE GENERIC BRIDGE ADDRESS VALUE

RESERVED
EQUALS ZERO.

NUMBER_OF_FDSE_ADDRESSES
EQUALS THE NUMBER OF FDSE GLOBAL ADDRESSES IN THE FLUSH PDU. NEVER EQUALS ZERO.

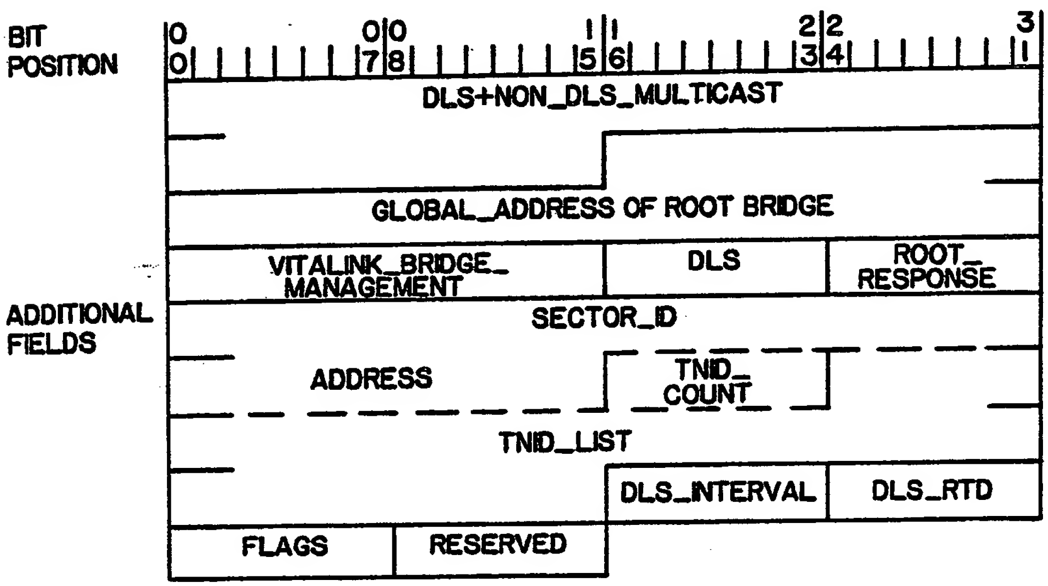
Nth_FDSE_ADDRESS
IDENTIFIES A SINGLE DESTINATION GLOBAL ADDRESS FDSE WHICH IS IN THE PROCESS OF MOVING FROM A STP TO A DLS PATH OR AGING OFF OF A DLS PATH. THE EMPTY FLAG IS DEFINED THE SAME AS FOR THE DLS PDU ABOVE.

FIG.4.3B

FIG.4.5

ROOT RESPONSE PROTOCOL DATA UNIT

ROOT RESPONSE PDU FORMAT



SECTOR_ID
CONTAINS THE FOLLOWING FIELDS
ADDRESS=ROOT ADDRESS
TNID_COUNT=NUMBER OF TNID_LIST ENTRIES (1–7)
TNID_LIST=A STRING OF 1 OCTET TRANSMIT NETWORK ID (TNID) VALUES DEFINING THE PATH FROM THE ROOT. THE FIRST OCTET CONTAINS THE ROOT TNID, THE SECOND OCTET THE SECOND BRIDGE TNID,ETC.

DLS_INTERVAL
EQUALS THE CONFIGURED DLS_INTERVAL IN THE ROOT BRIDGE.

DLS_ROUND_TRIP_DELAY (RTD)
EQUALS THE CONFIGURED DLS_RTD IN THE ROOT BRIDGE.

FLAGS
CONTAINS THE FOLLOWING FLAGS
FIFO_REQUIRED=TRUE/FALSE
TRANSMIT_FLUSH_PDU=TRUE/FALSE

RESERVED
EQUALS ZERO

FIG.5 DLS DATA STORES

THE FOLLOWING DATA STORE CHANGES/ADDITIONS ARE REQUIRED BY DLS.

FIG.5.1 GENERAL DLS (GDLS) VARIABLES

GLOBAL GDLS VARIABLES

VARIABLE NAME	POSSIBLE VALUES,DEFAULT	REC
CONFIG_DLS_ROUND_TRIP_DELAY	4-32 (SECONDS),4	YES
DLS_ROUND_TRIP_DELAY (RTD)	ROOT'S CONFIG DLS RTD,CONFIG_DLS_RTD	D
CONFIG_DLS_INTERVAL	2-8 SECONDS,4	YES
DLS_INTERVAL	ROOT'S CONFIG_DLS_INTERVAL,CONFIG_DLS_INTERVAL	D
CONFIG_SECTOR_ID	(ROOT ADDRESS,TNID_COUNT,TNID_LIST),0	YES
SECTOR_ID	ROOT'S SECTOR_ID,CONFIG_SECTOR_ID	D
CONFIG_FIFO_REQUIRED	TRUE/FALSE,TRUE	YES
FIFO_REQUIRED	ROOT'S FIFO_REQUIRED,CONFIG_FIFO_REQUIRED	YES
CONFIG_TRANSMIT_FLUSH_PDU	TRUE/FALSE,TRUE	YES
TRANSMIT_FLUSH_PDU	ROOT'S TRANSMIT_FLUSH_PDU,CONFIG_TRANSMIT_F...	YES

LOCAL GDLS VARIABLES

VARIABLE NAME	POSSIBLE VALUES,DEFAULT	REC
DLS_NET COUNT	0-8,0	X
NEXT_DLS_BRIDGE	BRIDGE GLOBAL_ADDRESS,STP ROOT ADDRESS	NO
NEXT_DLS_BRIDGE_DISCARD_TIME	CURRENT_TIME+5 (DLS_INTERVAL),0	NO
NEXT_DLS_INTERVAL	CURRENT_TIME+N (DLS_INTERVAL)-1 TIC,0	NO
SHORT_TIMERS_INVOKED	0-65535 ,0	X
DLS_ROUND_TRIP_DELAY_EXPIRED	0-65535	X
GENERATE_DLS_PDU	TRUE/FALSE,FALSE	NO
DLS_MULTICAST	DLS_MULTICAST,0x09002C...	S
DLS_HELLO_MULTICAST	DLS_HELLO_MULTICAST,0x09002C...	S
DLS_INLINK_HELLO_MULTICAST	DLS_INLINK_HELLO_MULTICAST ,0x09002C...	S
DLS±NON_DLS_MULTICAST	DLS±NON_DLS_MULTICAST,0x09002C...	S
ROOT_RESPONSE_RETRANSMIT_COUNT	0-4,0	NO
INLINK_HELLO_TIMER_STARTED	TRUE/FALSE,FALSE	NO
SEG_NUMBER	0-0xFFFFFFFF,0	NO

FIG.5.2 TDSE VARIABLES

VARIABLE NAME	POSSIBLE VALUES,DEFAULT	REC
STATE	.../DLS FOWARDING/DLS BACKUP/...	D

FIG.5.3 TDSE VARIABLES

VARIABLE NAME	POSSIBLE VALUES,DEFAULT	REC
ENABLE_DLS	TRUE/FALSE,TRUE	S
FORCE_DLS	TRUE/FALSE,TRUE	S
GENERATE_DLS_PDU	TRUE/FALSE,FALSE	NO
FDSE_TOTAL	0-65535,0	X
FDSE_MAXIMUM	0-65535, TDSE NET_SPEED 1000	S
FIRST_BLE	POINTER TO BLE WITH LOWEST NET_COST,0	NO
LAST_BLE	POINTER TO BLE WITH HIGHEST NET_COST,0	NO
BLE_COUNT	0-4,0	D
UNUSED_BLE_ID LIST	1/0,2/0,3/0,4/0	NO
FLUSH_PDU	POINTER TO FLUSH PDU BUFFER/) 0	NO
NEXT_FLUSH_ADDRESS	POINTER TO NEXT FDSE ADDRESS FIELD IN FLUSH PDU/0	NO

FIG.5.4 BRIDGE LIST ENTRY (BLE) VARIABLES

VARIABLE NAME	POSSIBLE VALUES,DEFAULT	REC
BLE_ID	1-4	NO
ADDRESS	ASSOCIATED DLS BRIDGE GLOBAL_ADDRESS	NO
SECTOR_ID	ASSOCIATED DLS BRIDGE SECTOR_ID	NO
NET_COST	ASSOCIATED DLS NETWORK(S) NET_COST	NO
MY_COST	ASSOCIATED DLS BRIDGE MY_COST	NO
EXTENSION_ID	(BRIDGE GLOBAL_ADDRESS TNID OF EXT NET)/0	NO
DISCARD_TIME	CURRENT TIME 5(GDLS DLS_INTERVAL)	NO
NEXT_BLE	POINTER TO NEXT BLE POINTER/0	NO

EVENTS \ STATES	PRE-FORW'G 1	FORW,G 2	BACKUP 3	DLS FORW'G 4	DLS BACKUP 5	OTHER 6
HELLO STP PDU CHANGES SECTION 6.2.X		–/5 X=1				
NV TIMER ALARM NEW ROOT CHANGES SECTION 6.2.X				2 X=2	3 X=2	
FMP EACH 2 SEC PROCESSING CHANGES SECTION 6.3.X				– X=1	– X=1	
FMP EACH TIC PROCESSING CHANGES SECTION 6.4.X				– X=1	– X=1	
DLS HELLO PDU PROCESSING SECTION 6.5.X	– IGNORED	– X=1	– IGNORED	– IGNORED	– IGNORED	– IGNORED
DLS PDU PROCESSING SECTION 6.6.X	– IGNORED	–/4 X=1	– IGNORED	– X=1	– X=1	– IGNORED
FLUSH PDU PROCESSING SECTION 6.7.X	– IGNORED	– X=1	– IGNORED	– X=1	– X=1	– IGNORED
ROOT REQUEST PDU PROCESSING SECTION 6.8.X	– IGNORED	– X=1	– IGNORED	– IGNORED	– IGNORED	– IGNORED
ROOT RESPONSE PDU PROCESSING SECTION 6.9.X	– IGNORED	– X=1	– IGNORED	– IGNORED	– IGNORED	– IGNORED
INLINK HELLO TIMER ALARM SECTION 6.10.X		– X=1				
STP SECTION 3.3.1.7 PROCESSING CALL SECTION 6.1.X THEN EXECUTE 3.3.1.7	– X=3	– X=3	– X-3	2 X=3	3 X=3	– X=3
STP SECTION 3.3.1.8 PROCESSING CALL SECTION 6.1.X THEN EXECUTE 3.3.1.8	– X=3	– X=3	– X=3	2 X=3	3 X=3	– X=3
STP SECTION 3.3.1.9 PROCESSING CALL SECTION 6.1.X THEN EXECUTE 3.3.1.9	– X=3	– X=3	– X=3	2 X=3	3 X=3	– X=3

IN THE ABOVE MATRIX, A BLANK RECTANGLE MEANS THAT THERE ARE NO RELEVANT CHANGES AND/OR ACTIONS ASSOCIATED WITH THE EVENT/STATE OPERATION.

FIG.6
DLS OPERATION

...ngereicht / Newly filed
Nouvellement déposé

FIG. 6.5

DLS HELLO PDU PROCESSING

HELLO'S SOURCE_NID TDSE TDSE TNID=XDS INLINK	n	y	y
GDLS INLINK_HELLO_TIMER_STARTED=TRUE		y	n
SET GDLS NEXT_DLS_BRIDGE=HELLO SOURCE_ADDRESS		x	x
SET GDLS NEXT_DLS_BRIDGE DISCARD_TIME=		x	x
CURRENT_TIME+5(GDLS DLS_INTERVAL)		x	x
SET GDLS INLINK_HELLO_TIMER_STARTED=TRUE			x
START INLINK HELLO TIMER ALARM,PERIOD=1 SECOND			x
DISCARD DLS HELLO PDU	x	x	x